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Canada - Saskatchewan Renewables — Conservation Demonstration Program

Final Report





CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;
- To create employment in new or existing industries;
- To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

However, neither the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, nor the Government of Canada as represented by Energy, Mines and Resources Canada, accept liability for any errors, omissions, or inaccuracies that may be included in or derived from this report, nor do they assume any liability with respect to the use of, or actions resulting from the use of, any information contained in this report.

The Conservahome Project: An Overview

**Final Technical Report
on a Renewables-Conservation Demonstration Program Project**

**Conducted By
The Saskatchewan Research Council**

**And Supported By
Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada**

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**Miscellaneous
Report FP-14**

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SECTION I

GENERAL SUMMARY OF THE PROJECT

INTRODUCTION

The Conservahome Project was devised in the fall of 1979 under the joint initiative of the Saskatchewan Office of Energy Conservation and the Saskatchewan Housing Corporation. It was funded by the Saskatchewan-Canada Conservation and Renewable Energy Demonstration Agreement (CREDA).

Saskatchewan has been much acclaimed for its role in developing new energy-efficient housing, but within the province these activities are seen as an attack on only a small part of a much wider-ranging problem. In facing the energy future it is proper to take all reasonable steps to avoid building energy-obsolescence into the new housing stock, but the main thrust should be directed at existing housing. This presents problems on a considerably larger scale. The field of retrofit is beset with technical, economic and social obstacles, and the government cannot implement effective retrofit programs without first defining these obstacles and finding ways around them. These considerations are the basis of the Conservahome Project.

The primary aim of the Project was to define the technical and economic problems of retrofit by conducting retrofit work on six houses under closely controlled conditions. The second aim was to use the six houses as demonstrational centres for the general public and the building industry. The third aim was to transfer the technology of retrofit to builders and sub-trades, particularly those involved in the project.

The details and findings of the Conservahome Project will be published in seven reports. This first report is an overview of the Project

and is concerned with the broader technical, economic and social issues. Each of the remaining six reports will concentrate on an individual house. These will look at the special problems encountered in each house, and will discuss the advantages and disadvantages of the retrofit strategies that were adopted in each case.

2 THE STRUCTURE OF THE PROJECT

The project was managed by the Saskatchewan Office of Energy Conservation (OEC) and the Saskatchewan Housing Corporation (SHC). SHC was responsible for the technical aspects, and OEC was responsible for the demonstrational aspects and energy conservation policy. The detailed technical aspects were contracted by SHC to the Saskatchewan Research Council (SRC). The operation of the demonstration program was contracted by OEC to a private sector consultant.

The terms of reference of the Project called for the retrofit of six houses, one in each of six centres: Maidstone, Prince Albert, Swift Current, Moose Jaw, Weyburn and Yorkton. The centres were selected mainly for their wide geographic spread (see figure 1) and for their relatively large populations - both of which are important factors in demonstrational impact. The town of Maidstone was the exception: this town is located on the edge of the Saskatchewan heavy oil resource, and was included to give coverage of rural factors and oil-heating problems (natural gas is prevalent in most of the larger population centres in Saskatchewan).

At each of the centres local realtors were asked to prepare a short list of houses, currently for sale on the open market and meeting a set

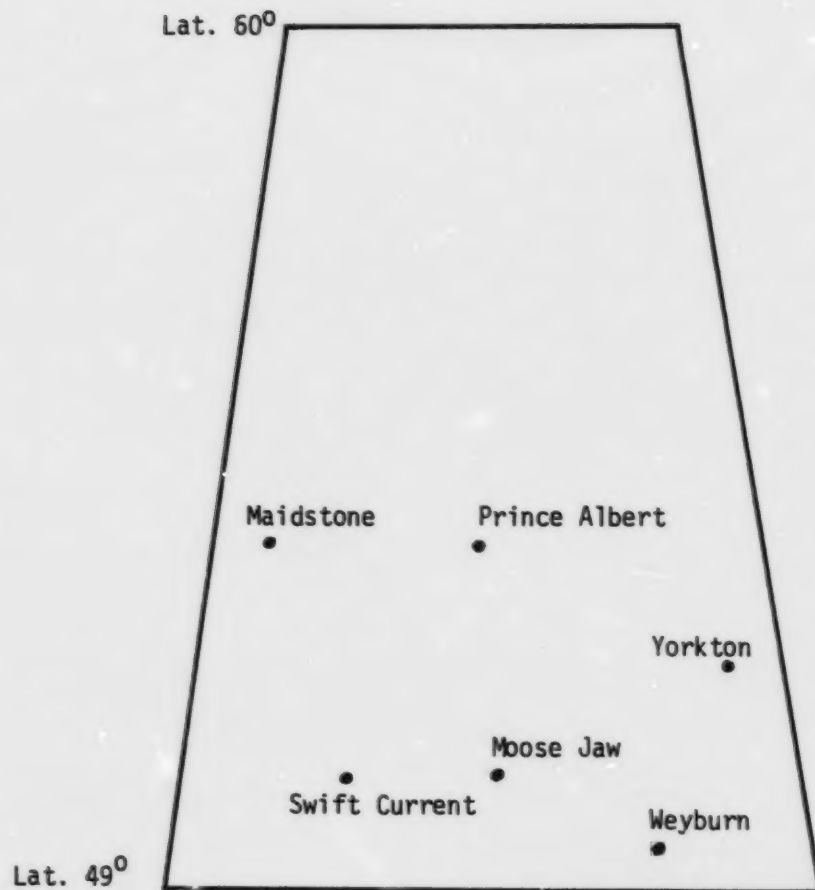


Fig. 1. Location of Conservahomes

of specified requirements (to be discussed later). These houses were then given a brief inspection by a team drawn from SHC and SRC. The most appropriate house was then selected and a recommendation for its purchase was submitted to a Management Committee, made up of senior people from SHC and OEC. Once approval was given, SHC arranged the purchase of the houses and then handed over the keys to SRC for the technical investigation stage.

The aim of the technical investigation was twofold: the first part was to completely define and document the houses, both in terms of structure and energy performance; the second part was to design a retrofit package for each house. The criteria that were used in designing the retrofit package are discussed later. Previous owners were consulted to determine lifestyle patterns, energy usage and any structural problems of the houses. The fuel bills were recovered from the public utility companies with the owners' consents, and were analysed. If the house plans were not available, as was usually the case, detailed measurements of the house were taken. These were then passed to a drafting service for rendering into a set of as-built plans. The houses were given an extensive and detailed inspection to identify the hidden structural details, the insulation levels, the state of the vapour barrier and the general condition of all the surfaces and equipment. The furnaces and water heaters were inspected, and the efficiency of the furnaces was measured. A complete infra-red scan was done on each house by a consultant. All problem areas detected by this technique were recorded on film and compiled, by the consultant, into a formal report on each house. Another consultant was engaged to conduct airtightness tests on each house and submit a detailed analysis on each.

Once all this information had been assembled, SRC prepared an evaluation of each house. This summarized the main elements of the house (with numerous photographs) and outlined a proposed retrofit strategy. It also included an evaluation of the rehabilitation work needed on the house, a preliminary estimate of the costs of retrofit and rehabilitation, and an estimate of the cost-effectiveness of the proposed retrofit measures. In support of this documentation a brief appraisal was prepared on each house, summarizing any legal, by-law or code problems that would affect the proposed work.

These documents were submitted to SHC, who in turn submitted them to the Management Committee for approval. When approval was given, SHC requested SRC to translate the retrofit and rehabilitation proposals into a contract document and a set of plans. The plans were required to show the house in its existing state, and the way it would look when finished. They were also to include detail drawings of all the required work. This was done by the drafting sub-contractor under SRC supervision. The contract document followed a format developed by SHC for this project, and included a very detailed specification of each item of work - in acknowledgement of the fact that many of the techniques would be completely new to many of the building contractors.

After approval of the contract documents and the plans by SHC, calls for tender were placed in the newspapers and copies of the contract documents and plans were sent to each applicant. Tenders were handled in the usual way by SHC, though the whole process went less smoothly than in a conventional large-building contract. Some of the aspects of this will be discussed later.

Selected contractors were authorized by SHC to proceed with the work. During this phase of the Project, both SRC and SHC staff made several visits to each site to inspect the work and explain some of the new techniques to the contractors and their sub-trades. The work was comprehensively documented in photographs and films by sub-contractors engaged by OEC.

Acceptance inspections were carried out by SHC and SRC on completion of each house. In most cases the contractors were required to do a lot of remedial work before the work was accepted and the contract closed.

Towards the end of the construction work most of the contractors were given supplementary contracts dealing with interior decoration to improve the appearance of the houses for demonstration. On completion of this work the houses were furnished and OEC assumed possession of the houses for the demonstration phase. Around this time the houses were given a repeat airtightness test and a thermographic scan, both of which were documented and reported as previously done.

The demonstration phase was initiated with a series of official openings attended by local dignitaries and representatives of the provincial and federal governments.

During the demonstration phase the houses were open to the public for a few hours every day, and were staffed by one or two guides who had been trained in the retrofit techniques used throughout the project. The demonstration was supplemented by a series of brochures covering various aspects of residential energy conservation. Also, each house had a photographic display that covered the work done on all six houses. Retrofit workshops were held occasionally at each house, and this was an

important aspect of the demonstrational program.

At the end of the demonstrational phase the houses were put up for sale on the open market.

3 HOUSE SELECTION CRITERIA

The houses were selected on the basis of three sets of criteria: technical, demonstrational and economic.

Technically, the houses were required to give a wide age coverage, ranging from the types built in 1920 to those built in the late 1970's. The houses were also required to show a wide range of styles and a wide range of retrofit problems. Demonstrationally, emphasis was placed on the location of the houses (accessibility, parking space, etc.) and on the likely appeal of the finished house.

The economic criteria were the strongest. The main aim was to concentrate on the low-cost sector of the housing market and determine the cost effectiveness of various retrofit measures and levels of retrofit. This aim was translated into the following budgetary allocations:

Allocation	Total	Average per house
For house purchase	\$261,000	\$43,500
For rehabilitation	\$42,000	\$7,000
For retrofit	\$36,000	\$6,000

Table 1 Budgetary Allocations

A further economic criterion was that an attempt should be made to select houses with good re-sale potential. The choice of house was therefore influenced in part by the likely trend of the housing market in the neighborhood.

4 RETROFIT CRITERIA

Right at the beginning of the project it was generally recognized that the retrofit design should not be contrived: that is to say, the retrofit design should be appropriate to the house, and should be a reasonable attempt to solve the energy consumption problems of the house. For example, if the exterior shell of a house was already in need of repair and upgrading, then the house would be a potential candidate for a new exterior shell with upgraded insulation.

The six retrofit houses were required to demonstrate a wide range of retrofit options and, at the same time, a range of retrofit levels - the level being gauged according to the cost of retrofit. The houses were therefore selected, in part, on the basis of how well they fitted into this general strategy. It follows that some of the retrofit design was already pre-determined at the time of the house purchase. Even so, there was enough flexibility in the situation to make each house a self-consistent retrofit exercise, and at the same time to make the lessons of each house complement those of the others.

In the planning stages of the project, 'retrofit level' was related to the amount of funds to be provisionally assigned to each retrofit package. Two low-level retrofits (\$3,000), three medium-level retrofits (\$6,000) and one high-level retrofit (\$12,000) were to be conducted. In

the low-level retrofits, the aim was to demonstrate the most effective way to utilize money available through existing government assistance programs (\$500 grant from the Canadian Home Insulation Program and the \$1,000 interest-free loan from the Warm Up Saskatchewan Program). The aim of the high-level retrofit was to determine the costs and techniques required to upgrade the thermal performance of an existing house to a level comparable with that of super energy-efficient new housing, in which the space heating requirements are typically 80% lower than in an equivalent house of conventional construction.

It was expected that, in addition to their demonstrational role, most individual retrofit measures would be considered cost-effective at the present time. However both the medium-level and high-level retrofit packages would include individual retrofit measures which could not be considered cost-effective at the present time, but which might well become so as energy prices increase.

The difficulty and inaccuracy involved in estimating costs and benefits of the medium and high-level retrofit packages in the planning stage become apparent during the job tendering phase (to be discussed later).

At a more specific level, it was planned to demonstrate the following retrofit options:

- a range of wall retrofits (inside, outside, and inaccessible).
- a range of attic retrofits, according to attic design.
- a range of basement retrofits, according to basement type, condition and level of development.
- a range of door and window retrofits.
- a range of furnace retrofits.

In addition, it was hoped that the houses would include special problems such as dormer construction, slab-on-grade foundation, fireplace or stove, masonry construction, etc.

5 DIFFICULTIES IN SELECTING HOUSES

The impossibility of adequately meeting all the criteria was soon made apparent. The major conflicts involved the technical and economic criteria. In addition, the housing market offered a very limited selection; in Maidstone, for example, there were only two houses on sale and neither was particularly suitable.

Some very good houses were rejected because of their high cost; others were rejected because of their poor re-sale potential. In the latter case, one of these houses was a slab-on-grade design that might have offered some challenging retrofit problems. Only one masonry house came up for sale during the purchasing phase. This met every single criterion of the project, but its construction was so unique and atypical that there would not have been much point in demonstrating how to retrofit it - both SRC and SHC agreed on that point.

Looking back at all the problems that were encountered, it is surprising that such a high proportion of the criteria was met. Both SHC and SRC are fairly satisfied with the selection, with, perhaps, the exception of the Yorkton house, which bears too much similarity to the other post-1960 houses in the project. But this was turned to advantage by modifying the retrofit strategy.

6 DIFFICULTIES IN DESIGNING THE RETROFIT PACKAGES

The six houses were dealt with on staggered schedules, so that some of the houses were already being tendered for retrofit while others were still being purchased. As soon as the first tender costs were revealed it was clear that either the contractors were overestimating or SRC had underestimated. This discovery had a major effect on the subsequent course of the project.

As each new set of quotations was opened, the costs were found to be much greater than estimated. SHC started negotiations with the contractors, and instructed SRC to design alternative retrofit schemes with a lower cost.

This went fairly well for a short time until it became evident that, through this process, a significant number of optional retrofit measures would be deleted. The end result would be a project which would not be comprehensive in terms of examining a wide range of options. Also, the overall demonstrational impact of the project would be reduced. The management committee therefore decided to proceed with the retrofit packages, substantially as they were originally designed, while trying to keep their costs to a minimum. This decision was taken with the full knowledge that, while a number of the retrofit measures would not be cost-effective, the project would make a valuable contribution to the general body of information regarding retrofit. The inclusion of high-cost retrofit measures resulted in the following categorizations: one house has a low-level retrofit, one house has a medium-level retrofit and four houses have a high level retrofit.

7

SUMMARY OF THE SIX HOUSES

Comprehensive details of the six houses, together with details of their retrofit packages, will be given in the six reports that follow this one. In this overview, the summary of the houses is limited to a brief discussion of the main features, an outline of the retrofit strategy, and a brief appraisal of the house's impact on government retrofit programs. The houses are discussed individually and in chronological order.

7.1 Maidstone



Description:

Built in 1920. One-and-a-half storey wood-frame construction on a shallow foundation, with partly excavated (dug-out) basement. Has been subject to at least three major modifications, all of poor quality.

Main floor area is 820 square feet, excluding verandah and cold porch. Construction of walls is 2 by 4 studs with 1" lapboard siding, sheathing paper and stucco. Interior surface is badly deteriorated 'Tentest' covered up with

recently-applied panelling. The house has no vapour barrier and no insulation worth speaking of. All parts of the house are badly run-down.

The house has an oil-fired furnace of recent vintage and in good condition. The domestic hot water tank was electrically heated and in need of replacement.

Fuel records are incomplete, but from available information it is deduced that the annual space-heating bill would be \$1630 at current oil rates.

Retrofit Summary:

The heated envelope of the house was reduced to include only the main floor. The basement and attic room, each of them unsuitable as living space, were taken outside the warm envelope. The badly deteriorated verandah and porch were removed.

The main floor was stripped back to the wood frame, insulated, given an airtight vapour barrier, and re-drywalled.

All doors and windows were replaced, and the passive solar design was improved. Some poorly placed windows were eliminated entirely.

The basement was cleaned up and partly insulated to maintain its temperature above freezing. It is now, essentially, a deep crawl space that can be used for storage.

The furnace was fitted with flame-retention burners.

The domestic hot water tank was replaced and relocated on the

main floor, with a pre-heater unit using waste house heat. Estimated reduction in energy consumption is 90% on space heating and about 20% on water heating.

Impact on retrofit programs:

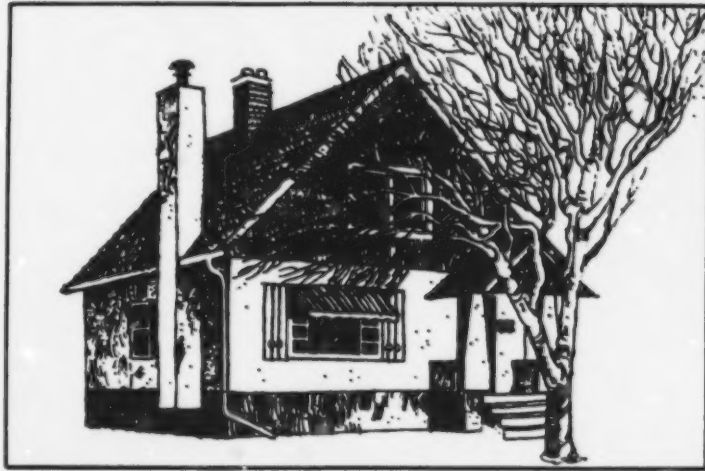
This house was in very bad condition. It is now a fairly attractive house with a good interior finish and low fuel bills. It should be able to withstand the effects of fuel cost escalation, and should be a viable residence for at least another twenty years. The neighbouring houses on the block are relatively new and of good quality. This house was a threat to local property values, but the threat has been ameliorated by the raised quality of the house.

The house will recover most of the money spent on it, at the time of re-sale, but this is due more to a local housing boom* than to any intrinsic merits of the work done on it.

In any government retrofit programs there would be a natural tendency to demolish and replace houses of this type. The economic experiences on this project have shown that the issue is not clear-cut; there may be mitigating factors that would make it more cost-effective, and more desirable, to invest in retrofit rather than replacement. The house emphasizes the need for a reliable and comprehensive set of guidelines for determining whether to adopt a policy of restoration or replacement.

* Whether this boom persists or not will depend on how the heavy oil resources in this area are developed over the next few years.

7.2 Weyburn

**Description:**

Built in 1929. One-and-a-half storey balloon wood-frame with full concrete basement. Has been given at least three major modifications, of varying quality.

Plan area is 680 square feet. Walls are 2 by 4 stud frame with irregularly placed furring strips on the inner face, finished in lath and plaster. Exterior stucco is in fairly good condition. Interior surfaces have been refinished recently and are of good quality.

Basement is essentially undeveloped. Foundation walls are good for this age, but some renovation is needed. Attic is high and structurally sound.

Attic and walls poorly insulated with vermiculite. Thermograph shows patchy insulation in walls, with only about 50% coverage. There is no vapour barrier.

Furnace and domestic hot water heater are gas-fired and need replacing. A modern zero-clearance fireplace, with fresh air supply, has been installed recently, but with many installation faults.

True spacing heat costs cannot be determined because of fireplace use. It is estimated that, at current rates, the annual cost of space heating by natural gas would be \$630.

Retrofit summary:

In formulating a retrofit strategy, the deciding factor was the total absence of any kind of vapour barrier, and the economic impracticability of trying to install one. It was decided to seal the house as tightly as possible, to at least reduce one mechanism of moisture movement into the walls. But, because of the absence of vapour barrier, there would still be a high rate of moisture movement into the walls by diffusion through the lath and plaster. To withstand the effects of moisture accumulation, it was decided to insulate the walls and ceiling with vermiculite. The house framing allowed most of this to be done by pouring from the attic. A very bad exterior door was replaced. Most of the double-hung windows were in good condition, but with more openable

sections than was necessary for ventilation. Some of the openable sections were sealed shut.

The basement was repaired and fitted with an insulated stud-frame wall on the interior. This has added considerably to the value of the house.

It is estimated that the space heating bill will be reduced by 73%.

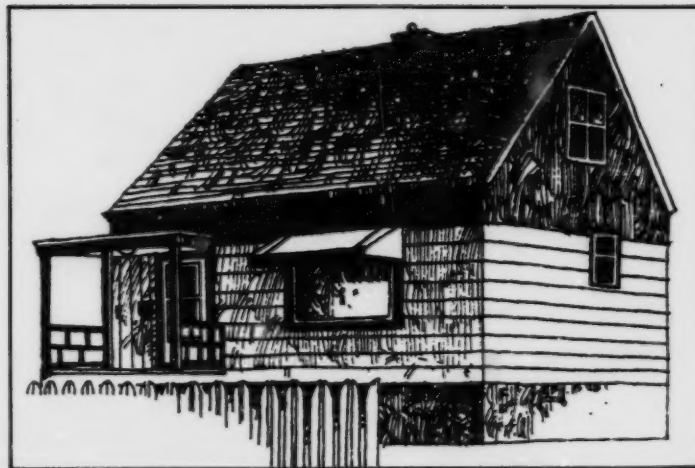
Impact on retrofit programs:

This house presents a paradox: if the house walls are thermally poor, but in good condition, there is not much that one can do to extend its life - without costly and sometimes extensive retrofit work. On the other hand, if the house interior surfaces had been in bad condition, it would have been relatively easy to make the house far more energy-efficient, in combination with rehabilitation of the interior surfaces.

The experience on this house has shown that access to the walls is all-important. If there is poor access, the contractor is 'working in the dark' and can achieve a good retrofit only by taking a great deal of care. This is costly.

The presence or absence of a vapour barrier should be considered as a major factor when determining what to do with the house.

7.3 Swift Current



Description:

Built in 1946. This is a classic 'wartime six' design, consisting of a one-and-a-half storey wood frame on full concrete basement. The house has not been modified from its original form. The plan area is 612 square feet. Wall construction is 2 by 4 stud, platform built. Interior surfaces and frame are sound. Exterior is sided with deteriorated cement-asbestos board. Walls are insulated with R7 Kraft-backed mineral wool batt, with about 2" air space on exterior.

Roof is insulated between rafters with same type of batt. The construction at the junction of roof and walls is a major source of infiltration.

Basement is in good condition, but unuseable as living space because of old wood-burning furnace (converted to natural gas) which takes up most of basement space. Domestic hot water tank is gas-fired and will soon need replacing. Windows mostly double-hung with storms. Some need replacing, others can be rehabilitated.

Ground around house is sandy and relatively unobscured by paving. Space heating bills reflect atypical house occupancy (only one occupant). Estimated annual space heating bill with normal occupancy is \$366.

Retrofit summary:

The deteriorated siding, the need to repair cracks in the concrete foundation, and the ease of access all around the house - all of these factors suggest that the best way of sealing and insulating the house is to add vapour barrier and insulation on the exterior. It was out of the question to do this with a wood-framed re-skinning approach, because of the absence of any roof overhang. This would have involved considerable costs in extending the roof. The house was therefore insulated with a 2" layer of styrofoam, and the roof was extended with trim board. The styrofoam insulation was taken 2 ft. below grade.

A major design problem was presented in the attic: namely, how to route the vapour barrier and insulate for the best effect. The technical factors are too involved to be included here.

Some windows were replaced (mainly for demonstrational purposes) and some were retrofitted.

The 'octopus' furnace was removed and replaced with a coil heating system fed from a domestic hot water tank installed in its own airtight enclosure. This design was adopted because of the low space heat demand of the retrofitted house.

The reduction in annual space heating costs is estimated to be 78%.

Impact on retrofit programs:

This is typical of hundreds of thousands of wartime houses. Generally they have poor market value and are grouped together in low-cost housing areas. Structurally, many of them will survive for another twenty or thirty years, but thermally they are very poor and will not be able to withstand the effects of rising fuel costs. They are 'thermal slums'.

Perhaps the best thing to do with these houses is to give them an energy lifetime that matches their structural lifetime. The exterior insulation approach is particularly suited to this type of house, and is likely to be very acceptable to occupants because it improves the exterior appearance and does not disrupt living conditions too much.

7.4 Yorkton



Description:

Built in 1963. Single-storey wood frame on concrete basement. Partly developed basement.

The plan area is 950 square feet. The walls are stud-frame 2 by 4, platform built. Exterior is part stucco and part wood facing. All surfaces, interior and exterior, are in average-to-good condition. Vapour barrier is polyethylene sheet installed according to standard practice.

Walls are insulated with R9 high density glass fibre batt.

Ceiling is insulated with paper-wrapped mineral wool batt with estimated R8 to R9 thermal resistance.

Foundation is in excellent condition. Basement is about 20% developed and is uninsulated.

Doors and windows are in good condition, but seals need replacing. Windows are fixed-awning type double-glazed, and the sashes are very easily lifted off the seals. Furnace and domestic water heater are both in good condition and are natural gas units.

House shows widespread effect of high condensation, which is attributed to large family rather than airtight construction. Fuel bills were all available, showing an annual space heating bill of \$440, corrected to typical conditions.

Retrofit summary:

This house is fairly similar to the two other 'modern' houses in the project. It was decided to make this retrofit different from the other two by concentrating on window retrofit techniques and basement insulation techniques - both of which were appropriate to the needs of the house.

Some of the windows were converted to quad glazing (two doubles), others were converted to triples by the addition of a sealed storm, others were retrofitted by providing better seals and sash clamps.

Half of the basement wall was insulated with R20 batt in a stud frame. The other half was insulated with 2" styrofoam using the cap-con system. This has given a useful comparison of costs and technical problems of the two techniques.

The furnace and domestic hot water tank were provided with a sealed room, and an air-to-air exchanger was built into

a modified air-management system.

The whole house envelope was sealed according to the principles of the Saskatchewan Science Council publication: "Seal your house before re-insulating"*. The attic insulation was increased to R40.

The annual space heating bill will be reduced by an estimated 61%.

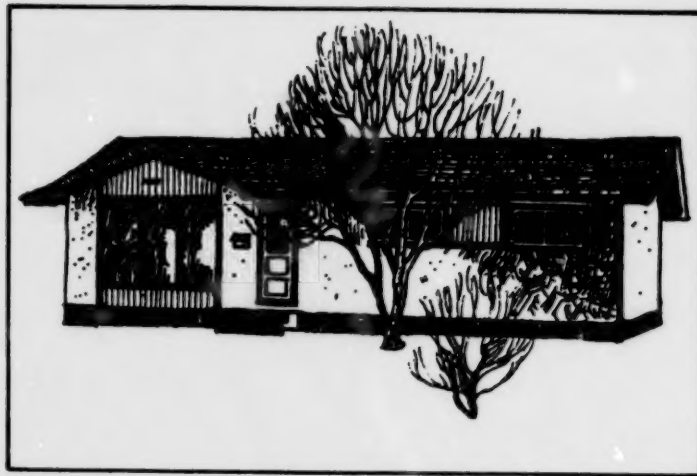
Impact on retrofit program:

The window retrofit was more thorough than would normally be done on a house. Taking out this component, the remaining retrofit package is a reasonable example of a medium-level retrofit on a fairly modern house. Anything more than this would involve a major job on the exterior walls, with a major jump in costs.

The basement retrofit was relatively simple in this case, due to the low level of basement development. Generally though, a house with this age would have more development in the basement. This would increase the cost of retrofit, and might inhibit the owner from doing any work at all in the basement.

* Distributed by the Saskatchewan Office of Energy Conservation.

7.5 Prince Albert



Description:

Built in 1966. Single-storey wood-frame on full concrete basement. The basement has been fully developed and is only partly insulated.

The plan area is 1050 square feet. The walls are 2 by 4 stud with platform construction. The exterior is mainly stucco, but with some small areas of decorative wood trim. All interior wall surfaces are in good condition. The vapour barrier is 2 mil polyethylene installed according to standard practice. The walls and ceiling are insulated with glass fibre high density batt, with estimated thermal resistances of R13 in the ceiling and R9 in the walls.

The foundation is in good condition. The basement has been developed with a 2 by 2 stud frame with wood panel finish and R7 batt over the top 4 ft. Thermograph studies have shown that this insulation is irregular and, in some cases, has slipped. The furnace and domestic hot water heater are gas-fired and in fairly good condition.

The doors have warped and are poorly sealed. The house faces north and has a considerable area of glass on its north wall. The windows are double glazed, but have very poor seals. The annual space heating bill for the house, derived from fuel bills, is \$300.

Retrofit summary:

It was decided that one of the three 'modern' houses in the project should be given a high-level retrofit. This house, because of its exterior condition and its finished basement, was suited to an exterior insulation approach. It was therefore designated for the high-level retrofit.

The house exterior was wrapped in 6 mil polyethylene and insulated outside this with R20 glass fibre batt, supported with a 2 by 4 stud frame added to the house exterior.

All the small windows were replaced with windows of higher quality. The ones on the north were reduced in size. The fixed sealed picture window on the north was converted to a triple glazed unit by fitting a sealed aluminum-framed storm.

The ceiling vapour barrier was sealed at all leakage points, and the ceiling insulation was increased to R50 by the addition of glass fibre batt.

The furnace was replaced with a new energy-efficient design and was provided with a sealed room enclosure.

An air management system was installed and provided with an air-to-air exchanger.

The estimated reduction in space heating bills is 75%.

Impact on retrofit programs:

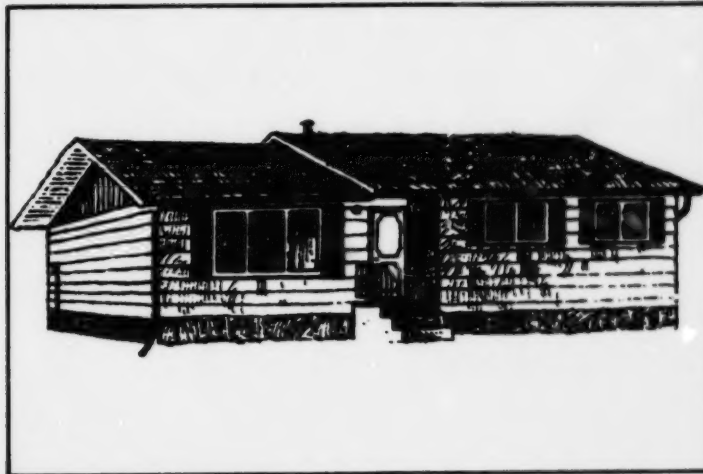
The main aim of this retrofit was to show that an existing house could be raised to the same level of energy efficiency as those new houses in the Energy Showcase*. It was felt that this might encourage owners to upgrade their existing house rather than buy a new one. The secondary aim was therefore to discover the costs of this type of retrofit.

The exercise has shown that the technical objectives can be achieved, though at considerable cost. In any retrofit program it is unlikely that this level of retrofit could be supported on a large scale.

When adding onto the house exterior on this scale, a number of non-productive costs creep into the operation, such as the costs involved in removing and replacing paving, and in relocating the service connections. When these are taken into account, the cost of an energy efficient wall is found to be far higher in retrofit than in new construction.

* 14 energy-efficient houses built in Saskatoon in 1980.

7.6 Moose Jaw



Description:

Built in 1976. Single-story wood frame with full concrete basement. Basement partly developed and insulated at the time of construction.

The plan area is 1150 square feet. The walls are 2 by 4 stud with platform construction. All surfaces are new and in good condition. The vapour barrier is 2 mil polyethylene installed according to standard practice.

Walls are insulated with R12 glass fibre batt and ceiling is insulated with R20 glass fibre batt.

Foundation appears to be in good condition. The basement wall is lined with a 2 by 4 stud frame. Kraft-backed R7 batt has been placed between studs, but not stapled in place. The top

4 ft. of the frame is covered with drywall but the bottom 4 ft. is uncovered.

Furnace and domestic hot water heater are gas-fired, and both are in good condition.

The exterior doors are thermal type, but poorly installed and poorly sealed. Windows are wood-frame casement type, but the seals are poor and the closing mechanism is weak.

The annual space heating bill, corrected to typical conditions, is \$315.

Retrofit summary:

All in all, this house is fairly typical of recent prairie construction. The higher levels of insulation and the basement development have raised its thermal efficiency, making it all the more difficult to achieve a cost-effective retrofit.

To fit in with the other two 'modern' houses, it was decided to give this house a low-level retrofit.

The infiltration performance of the house was improved by a comprehensive sealing job, according to the principles given in "Seal your house before re-insulating".*

Doors were re-sealed, windows were re-hung, re-sealed and fitted with sash locks.

The ceiling insulation level was increased to R45, and the attic hatch was insulated, sealed and provided with sash locks.

* "Seal Your House Before Re-Insulating". Sponsored by the Saskatchewan Science Council. Available through the Saskatchewan Power Corporation.

The basement insulation level was doubled to R14, and was done without removing the drywall section. The lower section of the wall was drywalled after the insulation was put in place. The furnace was tuned and a simple air management system was connected to the return air plenum. The reduction in space heating costs is estimated to be 50%.

Impact on retrofit programs:

The aim of this retrofit was to show what could be done with a low level of expenditure, in which most of the costs could be offset with government grants or loans.

All the retrofit work consisted of relatively small jobs with low material costs. The work done on this house might be considered a reasonable minimum retrofit, with considerable application to large retrofit programs.

The insulation work already done in the basement was 'atypical', and allowed a good retrofit at minimum cost. Normally, the basement would be more developed, and therefore unsuited to cheap retrofit. Alternatively, the basement might be undeveloped, in which case the cost of retrofit would be much higher. This house emphasizes the need for care in determining the costs of retrofit. It cannot be assumed that there is an infinite number of retrofit options, with small cost increments from one option to the next. Retrofit costs tend to take large jumps with each new job that is added. Therefore, in low cost retrofit, there are relatively few retrofit options.

SECTION II

TECHNICAL FINDINGS

On looking back at all the technical work in this project, the initial assessment of the house stands out as perhaps the most important step in the whole retrofit process. In the past, the assessment of the house has played a relatively minor part in the retrofit work that has been done, but with the accumulation of experience there has been a growing acknowledgement of its importance. The detailed assessments conducted in this project can be regarded as an upper limit, in terms of detail, complexity and level of effort. At the other end of the scale, and perhaps embracing the majority of retrofit work that has been done, the assessment consists of estimating the amount of insulation needed for a pre-determined retrofit task - irrespective of whether or not this might be the best thing to do. The ideal type of assessment falls somewhere between these two extremes, and is difficult to quantify. In selecting the most suitable type of assessment, it is useful to consider some of the factors involved.

A good assessment should look for answers to the following questions:

- What is the most appropriate way to improve the thermal efficiency of the house?
- Does the house have any existing problems that should be corrected before they are concealed by the retrofit work?
- Does the house have any existing problems that might be aggravated by the retrofit work?
- Will the retrofit work create new problems for the house?

- Does the house need rehabilitation, and, if so, can this be combined with the retrofit work so as to simplify and reduce the costs of each aspect of the work?
- If the house needs rehabilitation, does this suggest a better way of retrofitting the house?

Hidden within these questions is the concept of a house as a viable system, made up of various interacting components. The majority of existing houses may be thermally inefficient, but they are made up of components that are more or less in balance. Thus, the excessive air demands of an inefficient furnace are compatible with a leaky building envelope. Conversely, the infiltration induced by the furnace helps to reduce the risk of moisture damage in the building envelope.

Any modification to the house, whether designated as retrofit or rehabilitation, is potentially capable of shifting the balance of the various interactions in the house 'system'. In some cases this may not have any significant effect on the viability of the house, but in others it may present some kind of problem, such as accelerated moisture damage, or impairment of the air quality in the house. In some instances the state of the art has not advanced sufficiently for these problems to be foreseen. One example of this is the recent suspicion about frost build-up in flues, which may be a result of furnace oversizing. Any retrofit work on the building envelope will tend to increase the oversizing fraction of the furnace, which in some cases might lead to flue frosting. This technical digression has been included to make three points:

- In assessing a house, and selecting an appropriate retrofit strategy, serious consideration should be given to the viability and balance of the final house system.

- In some cases the consequences of an unbalanced system could be quite far-reaching in terms of damage to the structure or risk to the occupants. A good assessment should therefore take these factors into account, along with the more direct objective of saving energy.
- On the basis of hypothesis and very little else, the probability of undesirable interactions can be expected to increase with the level of retrofit. But this does not mean that low levels of retrofit are immune to such effects.

If the house were simply an assembly of non-interacting components it would be very easy to apply a series of retrofit formulas to the individual components. Unfortunately, the interactions are a significant factor. What is more, these interactions vary from one house to another, depending on the individual details of construction. Houses tend to be highly individualistic; even two houses of identical design could differ significantly in such things as modification or number of coats of paint - each of which can affect the detailed performance of the house. Accordingly, a formula approach to retrofit should not be adopted without a degree of caution or without an understanding of the factors involved. If the aim is to conduct a good retrofit, then it is advisable to approach each house as a unique problem, with its own unique set of interactions, constraints and retrofit needs.

SRC conducted a detailed assessment on each of the six houses in this project. On the three oldest houses the assessment required about three to four man-days of effort per house, but a large part of this was devoted to detailed measurements for the purpose of preparing as-built drawings.

On the three newest houses the assessment required one to two man-days of effort per house, since as-built drawings were available. With only six houses involved, there was not enough opportunity to develop a streamlined assessment procedure, but there was a noticeable improvement in skills throughout the assessment phase. On the basis of this working experience, it is estimated that a very thorough assessment could be conducted on a house in a matter of six man-hours or less, given skilled personnel and none of the extra documentation requirements that were needed in this Project. Given typical manpower costs and overheads, it is estimated that such an assessment would cost about \$160, exclusive of any travel penalties. For moderate to high levels of retrofit, costing more than \$4,000, the assessment costs would constitute about 4% of the total, and might be considered justifiable.

The age of the house can have an appreciable effect on the type of assessment and its associated cost. Houses built before 1950 display a wide variety of structural techniques, styles, materials and standards of construction. Often, such houses will have been modified at several stages during their history. Such modifications tend to be highly variable in quality, and may constitute major problems. The recommended starting point, for houses of this vintage, is to look first for the vapour barrier. The presence or absence of a vapour barrier, in any form, should be a major consideration when determining the retrofit strategy. If the house has no vapour barrier or nothing that serves as a vapour barrier, some attempt should be made to remedy the defect, if at all practicable. If it is not feasible to do this (a situation that appears to be fairly frequent), then the retrofit options should be judged in the light of how they will affect the moisture movement in the building

envelope, and how well they will stand up to this process.

Also in older houses, rehabilitation is often as important as retrofit. The assessment of the house should include both aspects, and should consider ways in which the two types of work can assist each other. For example: if the drywall is deteriorated, its removal and replacement would create an opportunity to do a better job on the wall insulation and the vapour barrier.

In very old houses that are nearing the end of their useful life, the assessment may have to consider the alternatives of upgrading or total replacement. The potential energy savings have to be measured against the anticipated life span of the house - which may be determined by structural considerations or by other factors, such as core renewal policies.

For houses built after 1950 the assessment can be simplified slightly and the cost reduced accordingly. There is a general similarity in the constructional technique (in Saskatchewan at any rate) and a general similarity in the problems that will be encountered. The assessment should therefore concentrate on the factors that make the house unique or unusual. These may arise from developmental work or from faults in the original structure. Often these faults are not obvious, and it requires experience to recognize the clues and interpret them. Signs of condensation can sometimes be traced to missing insulation or major air leakage paths through the vapour barrier, and are important clues to look for.

In view of the various factors discussed in this section, there is a good case for assigning a high level of importance to assessment procedures in retrofit projects. The cost of such assessment appears to

be defensible when moderate-to-high levels of retrofit are involved. At lower levels of retrofit, costing \$2,000 or less, the cost of assessment would add appreciably to the total cost. In this situation the cost must be balanced against the potential benefits. A good assessment can in some cases improve the effectiveness of the retrofit work, but its primary value lies in the area of problem avoidance. If a house has been previously retrofitted at the time of assessment, this work should be given careful inspection to determine its quality and its possible effect on other features of the house.

In assessing older houses for retrofit it may sometimes be necessary to make tough decisions, particularly if the retrofit work is to be conducted as part of a larger program, such as core renewal. The assessment has to take into account the probable duration of the house, and what funds, if any, should be invested in retrofitting it for its brief life span.

9 AIRTIGHTNESS TESTING

The airtightness tests were conducted under sub-contract by a consultant company that, at the time of this work, had already tested over 100 houses on other projects.

Tests were conducted on each house before and after retrofit. Usually, each test was repeated under two different conditions: the first with the house in its normal state and the second with all vents and openings sealed. The first test measured the overall airtightness of the house, and the second measured the airtightness of the house shell (distinct from openings such as vents, flues etc.).

The results are summarized in Table II on the following page. Two sets of figures are given: the first give the air leakage rate (in air changes per hour) with a pressure difference of 50 Pascals between the house interior and the exterior. The second set of figures are the air leakage rates with a pressure difference of 10 Pascals between the house interior and exterior. There is no generally reliable way of deriving the natural infiltration rate of the house from this data. The main value of the data in Table II is that they show the relative airtightness of the houses before and after retrofit.

It is pointless to look for any pattern in the data of Table II; each house has its own peculiarities that have to be taken into account. The main ones are as follows:

Maidstone:

The air change per hour data (ach) are obtained by dividing the measured air leakage rate (in cu. ft. per hr.) by the house volume (in cu. ft.). During the course of the Maidstone retrofit, the house volume was reduced from 13,500 to 6,000 cu. ft. Therefore, the ach data, before and after retrofit, relate to different house volumes.

Even so, the airtightness of the retrofitted house is low. This is due mainly to the fact that the furnace and most of its ducting were taken outside the house envelope. Where the ducting passes through the house envelope, the opening behaves something like an opening in the vapour barrier. The actual air leakage through this opening depends on how well the ducting and furnace body are sealed.

House	Air Changes per hour					
	With 50 Pa press. difference			With 10 Pa press. difference		
	Before retrofit	After retrofit	% reduction	Before retrofit	After retrofit	% reduction
Maldstone	7.99	1.73	78	2.51	0.60	76
Weyburn	9.97	5.76	42	3.13	1.65	47
Swift Current	12.33	3.24	74	4.66	1.09	77
Yorkton	2.64	1.01	62	0.94	0.29	69
Prince Albert	2.90	1.30	55	0.97	0.42	57
Moose Jaw	2.34	1.40	40	0.79	0.43	45

Table II. Results of airtightness tests

Weyburn:

It was known, before the retrofit was started, that it would be virtually impossible to achieve a satisfactory level of airtightness in this house. The main obstacles to airtight construction were the balloon frame construction and the open gaps at the top of the partition walls. In houses with this type of balloon framing, the second floor level joins into the exterior frame in such a way that air can flow between the floor joists and out into the wall. This part of the structure therefore acts like a very large infiltration opening, and it is virtually impossible to seal this opening without major structural changes and high cost.

Swift Current:

The high infiltration after retrofit is disappointing; the house should have performed better than this. The most probable source of air leakage is in the half-storey structure in the attic. The vapour barrier was interrupted by the framing at several points, and though great care was taken to seal the critical parts it looks as if this was not effective.

Yorkton and Moose Jaw:

These two houses were given similar specifications, based on the recommendations of the publication "Seal your house before re-insulating". The better performance of the Yorkton house can be attributed to the higher demands of the retrofit design

on this house. It should be noted that in both houses, as well as the Prince Albert house, the final airtightness performance falls close to the levels achieved in the new houses of the Energy Showcase.

Prince Albert:

The exterior of this house was wrapped with a new 6 ml polyethylene vapour barrier. A higher level of airtightness was expected, and it is disappointing that it wasn't achieved. The final airtightness performance of this house is similar to that of Moose Jaw or Yorkton, which suggests that a relatively simple sealing job can be as effective as a major vapour barrier replacement, given certain combinations of circumstances.

The airtightness test is usually conducted by a team of two people. It takes anywhere from one hour to two hours to conduct the test. The company that did the testing on the Conservahome Project did not have the facility for processing the data at site, and there was usually a delay of two days or more before the analysed data were submitted. A few commercial systems are now available, with testing equipment that includes a simple computer for on-site processing of the test data. The turnaround with this system is therefore shorter than was experienced in the Conservahome Project.

Assuming that a complete test can be done in two hours by a skilled operator and an unskilled assistant, the maximum cost of an airtightness test should be somewhere in the range of \$100 to \$150. This includes overheads, but does not include travel time. The cost of \$100 to \$150 is therefore typical of an urban situation, in which the test site is not too far from the offices of the testing company.

In a rural Saskatchewan situation it can be assumed that the test site is located 100 miles (on average) from the company office. This involves 3.5 hours of travel, with an associated manpower cost of about \$200 and a vehicle operating cost of about \$55. The total cost of a single rural test is therefore around \$370.

With costs like this, few private homeowners would be likely to make use of the airtightness testing method. In government retrofit programs, the economies of a large-scale operation might help reduce the testing cost to around \$80 to \$100 per home. These figures have to be doubled if the house is to be tested before and after retrofit.

In view of these costs it is appropriate to question the benefits of an airtightness test. What value is it to the contractor or the implementing agency? Consider the various aspects:

a) Diagnosis:

When the test is being conducted, the major leakage paths in the house envelope can be detected by a 'smoke stick'. It is instructive to the contractor to know the location of these leakage points. This knowledge induces him to think about the problems and find ways of overcoming them. But this diagnostic aspect can sometimes be achieved much more effectively by clamping a simple fan unit to the furnace chimney, where such exists.

b) Before-and-after comparisons:

This is of little direct benefit to the contractor or the implementing agency. It is mainly a research tool or a demonstrational tool. As a research tool it is helpful in developing sealing techniques. As a demonstrational tool it is helpful in showing the effectiveness of these techniques. Once the best techniques have been developed and proven, there is no real need for before-and-after comparisons.

c) As a source of design information:

In designing retrofit packages and assessing their cost-effectiveness, it is of great advantage to know the natural infiltration performance of the house. The airtightness test does not measure this; it measures the air leakage performance of the house in an artificial test condition. There is no

reliable way of deducing the natural infiltration rate of the house from the test data and, until such a way is found, the airtightness test is not much use as a source of design data.

d) As a means of testing quality of work:

Some contractors may wish to conduct their own airtightness tests, as a way of developing their own techniques and maintaining a certain quality of construction. This is already happening in new construction, but is not likely to happen in retrofit until the scale of activity increases.

e) As a means of controlling standards:

A standard airtightness testing procedure is now being developed by the Canadian General Standards Board. Ultimately, this will probably lead to a national airtightness standard for housing. If this comes into effect, the airtightness test will be used as a tool in implementing the new standard.

The future of the airtightness testing method can therefore be divided into two phases: short-term and long-term. In the short term, the main advantage of the technique will be found in the areas of research, development and demonstration. In these applications, the technique will play a valuable part in promoting the transition towards higher standards of airtight construction. At the same time, the technique itself should be subjected to research and development, aimed at improving its effectiveness, streamlining its application and reducing the cost of the test. - though there are now indications that these improvements are proceeding fairly quickly.

In the long-term, the main application of the technique will be found in the control of standards of airtight construction.

The implications for an implementing agency are fairly obvious. Such agencies have a few years of lead time in which to familiarize themselves with the technique, in preparation for its possible application as an inspection measure. In this interval, the implementing agencies should be taking a lead role in applying the technique or in supporting the related research and development. The cost of airtightness testing could be reduced significantly if the regulatory agencies were prepared to use it as a basic operating tool.

11

AN APPRAISAL OF THE THERMOGRAPHIC TECHNIQUE

Each of the Conservahome houses was given a comprehensive thermographic scan, both before and after retrofit, using a company that specialized in the application of this technique. The company compiled a detailed report on each house, consisting of photo-thermographs of the problem areas, standard photographic views of the same areas to pinpoint the location, and a brief interpretation of the thermographic data.

The thermographic technique has many problems in common with airtightness testing: the equipment is expensive and the operator has to know how to use it effectively. The cost of an isolated thermographic study is high, particularly if a large distance of travel is involved. Some of this cost can be eliminated by offering a more basic service. If the thermographic technique is adopted as part of a major retrofit program, it is not necessary to have a detailed report and analysis for each house - a photo-thermograph, attached to the offending part of the

structure, is perhaps all that would be needed.

It is instructive to look back at the thermographic studies conducted in the Conservahome Project, and consider how much they influenced the actual course of the retrofit work. The conclusions can be broken into two sections, according to the age of the houses.

In the three newest houses (1963, 1966 and 1976) the thermographic technique was not of much use. Most of the thermographs merely confirmed what is already known about such structures: thermal bridging at wall top plates, cold air infiltration at headers, reduced levels of insulation where vent stacks are set into exterior walls, and so on. On the Prince Albert house, a spot visual inspection showed that the panelled walls around the basement were insulated with a batt over the top 4 ft. The thermographic scan gave a very impressive picture, showing a considerable variation in the height of the insulated section, but this did not affect the ultimate retrofit design.

In post-1960 houses generally, it can be expected that a small percentage will have some kind of structural defect, such as a missing section of insulation. In such cases the thermograph would undoubtedly detect the problem, but it would make no kind of economic sense to use the thermographic technique in this 'shotgun' way*. The main application of the thermographic technique, in houses of recent construction, lies in confirming the existence of a suspected major defect - particularly where a destructive inspection would be out of the question.

The thermographic technique comes into its own in older houses, where the structural detail and the level of insulation could vary considerably

* It must be emphasized that the comments in this section relate to the Conservahome experience, and do not apply to new housing, where the thermographic technique has proven its potential as an aid to quality control. The thermographic companies now offer a service that

from one point to another. In such cases, the thermograph can be used to identify trouble spots, such as randomly-placed blocking that could impede the movement of poured insulation in a wall. Considerations such as this can play an important role in determining the retrofit strategy. But sometimes, the thermograph may not be needed at all. The three older houses in the Conservahome Project give an excellent demonstration of where the thermographic technique is useful and where it is not.

In the Maidstone house the drywall was in such bad condition that it had to be replaced. There was no good reason why the thermographic technique should have been used in preference to destructive inspection. A simple inspection at one or two points around the house was enough to confirm the structural details and lack of insulation. It was not important to know if there were any hidden structural problems, since these would become apparent once the wall was stripped.

In the Swift Current house a small piece of drywall was removed to allow inspection of the wall structure and insulation. This was all that was needed. The retrofit strategy was shaped by other factors, and it was not important to know if the insulation was defective at any point in the wall. The thermographic study therefore played no part in the retrofit design of this house.

On the other hand, the thermographic study played a very important part in the Weyburn house. About 50% of the wall area was insulated with vermiculite, and it was important to know which parts were insulated and which parts were being obstructed by blocking. The retrofit insulation work would have been far less effective without the information supplied

... has evolved considerably over the last year. The costs of the service are being reduced to the point where the economics are beginning to look more favourable, and it is likely that the technique will play a valuable role in future retrofit diagnosis.

by the thermographs.

If the thermographic technique is to be used as a design tool in large retrofit programs, this should be done sensibly and with discrimination, so as to minimize the costs. There is no point in using the technique where there are cheaper options - such as when the wall is to be stripped away - or where the hidden defects are either trivial or of no interest. The technique should be excluded in such cases, and its use should be concentrated where it will do most good, namely, in older houses with suspected defects and no alternative way of revealing the hidden parts of the structure. Used in this way, the technique can become an important part of retrofit assessment, with a low overall cost to the program.

12. PROBLEMS WITH HARDWARE

12.1 Air-to-air heat exchangers

Generally, these are still at an early stage of development. It may take a year or so before fully-debugged units with refined production designs are available. Currently there is some disagreement about the cost-effectiveness of these units.

During the course of the Conservahome Project, four main problem areas were noted:

a) Contractor familiarity:

The equipment is new and strange to most contractors. They don't know what it is, how it works, what it's supposed to do, or how to install it. The instructions that come with the units are sometimes not too helpful in this respect.

What is more, the whole problem of heat exchanger installation is still under review and development - in such things as its interconnection to dryers and heating systems, and the effect of vent placement on the pressure distribution in the house. An effective method has to be found for conveying even the basic technology to the building trades.

b) Availability:

Initially it was proposed to use three different heat exchanger models in the project, mainly for the purposes of comparison and demonstration, but only two models were available at that time. In the normal way, it is expected that all three types would be readily available in small quantities. This project was conducted at a time when the air heat exchanger industry was still in an early stage of development. Since then, the industry has grown rapidly and there is now a plentiful supply of heat exchangers of various designs.

c) Design

All the installed units could have benefitted from some design improvement. The four ports on the heat exchanger body were sometimes inappropriately sized and often poorly located for good connections to the various duct runs. Two of the units were fairly large (about the size of a domestic hot water heater) and, in some houses, it might be difficult to find a suitable place to install them. In the period that has elapsed since

this project there have been considerable improvements in heat exchanger design, but the above comments still apply to a number of designs.

d) The potential for structural damage

The two fans on the heat exchanger will have some effect on the air pressure in the house. If the internal air pressure of the house is increased, the rate of exfiltration through the various openings in the house structure will also be increased. The exfiltration process is the main source of moisture damage in the house structure, and the heat exchanger may aggravate this effect. To guard against this, the heat exchanger should never be installed in houses that have a poor airtightness performance. The alternative is to design the heat exchangers in such a way that they reduce the house pressure slightly. In doing this, some attention must be paid to the process of frosting. This occurs on the exhaust side of the heat exchanger, where the frost build-up restricts the size of the exhaust vent and tends to raise the house pressure. As a general guideline in government retrofit programs, the air heat exchanger should be seen as one of the last items in the list of possible retrofit measures. It should be employed only in cases where a considerable effort has been made to improve the airtightness of the house. There is no good guide as to how tight a house should be before an air heat exchanger can be installed. The risk of damage would be reduced if the heat

exchangers were designed to maintain a slightly reduced air pressure in the house, even under conditions of frost build-up.

12.2 Furnaces

Some of the Conservahome furnaces were overhauled and re-tuned, and some were replaced. Each strategy has its own problems.

Regarding re-tuning: the furnace tradesmen employed on this project were generally not too sure how to do this work and they had to be instructed. A recent investigation of this factor has shown that the furnace trade is skilled primarily in ductwork installation, and does not have much need or opportunity to acquire the requisite understanding of furnace operation. There is a need for better technology transfer in this area. Also, in small centres such as Maidstone, the nearest skilled tradesman may live as much as 50 to 100 miles away. When the travel costs are added to the direct costs of re-tuning, the economic advantages of this work may become negative. For instance, if a house has been retrofitted to the point where its annual space heating bill is \$150 with a 60%-efficient furnace, then the annual bill is reduced by only \$11 if the furnace is tuned to an efficiency of 65% (experience has shown that few furnaces can be tuned to an efficiency of 70% or better). Therefore, in most cases, the homeowner would have to pay up to \$50 to secure a first-year saving of about \$11. At first sight this might appear to be cost-effective with a pay-back of less than five years. However, it is possible that the re-tuning job would have to be done every two or three years, which would make the whole operation uneconomical.

In one extreme case in the project, the furnace filter was found to

be almost totally blocked with dust. Furnace efficiency measurements, with the filter removed, showed an increase of about 10% in the efficiency. Many home owners fail to appreciate the value of keeping the filter clean, and this suggests that the whole matter should be given more publicity than in the past.

Furnace replacement creates a number of problems. Consider a house whose structure has been retrofitted to a higher level of thermal efficiency: this has three effects on the choice of the replacement furnace:

- a) The furnace capacity can be reduced.
- b) Since the annual fuel consumption is much lower, the energy losses of an inefficient furnace are not much greater than those of an efficient furnace.
- c) It is now suspected that a grossly oversized furnace can produce excessive frost build-up at the top of the flue.

The ideal replacement furnace, therefore, is one that is sized to the reduced heating needs of the house, and one in which the increased efficiency is achieved with no great increase in price. Most of the new energy-efficient designs fall far short of these requirements: there are few designs available with thermal capacities of 55,000 Btuh or less, and even fewer that are priced in the same range as the traditional designs (some of the new energy-efficient designs are priced at \$2,500 or more).

Returning to the example of a retrofitted house with a fuel bill of \$150 per year: the fuel bill is reduced by about \$28 if the existing furnace (65% efficiency) is replaced by a new energy-efficient design with a rated efficiency of 80%. The furnaces available for this task are

priced typically \$500 more than a standard furnace, and are probably oversized for the house. Until the price of energy-efficient furnaces is reduced to a more cost-effective level, the traditional furnace designs will continue to be the best choice for retrofit.

In most existing housing, the furnace plays an important part in moisture control. The draft effect of the furnace flue creates a reduced pressure in the house, which causes infiltration air to be drawn into the house through the various openings and faults in the structure. This induced infiltration helps to reduce the exfiltration processes in the house, which are primarily responsible for moisture damage in the walls and attic. Therefore, when installing a new furnace in the house, some thought should be given as to how this might affect the balance of the infiltration/exfiltration process. Even an apparently unrelated job, such as adding more insulation to the house, can affect this balance by causing the furnace to cut-in less often. Drastic changes, such as the construction of an airtight room around the furnace, or the use of the new 'condensator' furnaces, will have a considerable effect on the infiltration/exfiltration balance. Such changes should not be adopted without first making sure that the house has been made reasonably airtight.

12.3 Humidifiers:

At least four of the Conservahomes have infiltration levels comparable with those of the new energy-efficient homes. This being the case, the houses are more likely to suffer from too much humidity rather than too little. These houses need an air-management system to control the humidity level; they do not need a humidifier. Nevertheless, the existing

Code requires a humidifier to be fitted to the heating system. Some thought needs to be given to modifying this Code, so that the extra cost of the humidifier is not incurred where it is not needed.

12.4 Dryer venting:

For optimum energy efficiency the dryer should be vented out of the house in summer and into the house in winter. The Code on appliance venting can be interpreted as prohibiting this. If the dryer is electrically heated, the main hazard from interior venting comes from the various chemicals (fabric softeners, etc.) that can get into the house air.

The alternative is to vent the dryer through the air-to-air exchanger, if one is installed. Some heat exchangers may not be suitable for this: they may be too small to handle the high air flow from the dryer, or they may be made from materials that do not stand up well to the high temperatures of the dryer exhaust.

The other alternative is to vent the dryer directly to the outside in all weathers, but this wastes energy. Many people vent their dryers into the house in winter, usually with some extra feature to remove lint. In a retrofitted house this may not be a good practice, since it can dump large amounts of moisture into the house and may produce excessive condensation on windows. The dryer exhaust is also a source of pollutants, and may significantly impair the air quality in a retrofitted house.

The acceptable technique for dryer venting will have to be worked out with those agencies who write or administer the relevant Codes, and some research is needed to define the pollutant effects of in-house dryer venting.

12.5 Water heaters:

Some energy-efficient domestic hot water heaters are now available, but are handled by only a few dealers. In the Conservahome Project some difficulties were experienced in finding the right dealers and in getting a reasonably prompt delivery. The trade suppliers do not seem to be familiar with the new energy-efficient hardware, still less do they stock it. This is a general conclusion, but it must be said that some suppliers are quite good in this respect - particularly those in the larger cities.

12.6 Windows:

Window designs have improved considerably over the last few years. The new designs use triple glazing to achieve higher thermal resistances, and pay much more attention to infiltration performance. The extruded vinyl frame designs are among the best in this new range. Two of these, representing the state of the art, were included in the Project. However, these windows were found to be relatively costly. At the moment, their costs may make them more appropriate for new energy-efficient housing than for retrofit.

12.7 Heating coils:

If a house is retrofitted to a very high level of energy efficiency, its space heating demands will fall well below the capacities of the existing range of furnaces (natural gas type). One solution is to use the domestic hot water tank to heat the house, by circulating the hot water through a copper coil mounted in the air circulation system. This was done in the Swift Current Conservahome, following the development of

this idea by one of the builders involved in the Energy Showcase.

At the time this system was installed at Swift Current, no fully-tested commercial units were available - though many systems have been installed elsewhere using car radiator coils or refrigeration coils. It is suspected that some of these systems may not have sufficient heating capacity. An improved coil design has been developed by a small company in Saskatoon. The prototype design, as tested by SRC, has enough heat output for a house built to high standards of energy efficiency.

The existing Code on gas appliances prohibits the use of domestic hot water heaters in this type of application, and a special dispensation was needed for the Swift Current Conservahome. Here again, it might be desirable to amend the Codes to allow the development of a promising new energy conservation technology.

12.8 Small hardware items:

Standard energy conservation hardware, such as door seals and night set-back thermostats, were readily available in a wide range of types. Contractors appeared to have no problems with the thermostats, though a few contractors did a poor job with seals.

Sash clamps can be expected to assume importance in the retrofit of windows and attic hatches. The selection is limited, and it is very difficult to get a good unit. The sash clamps used on the Moose Jaw Conservahome were chosen because they were readily available, but they are 'cheap and nasty' devices that are not designed for this application and detract from the appearance of a window.

ESTIMATING THE SPACE HEATING NEEDS OF A HOUSE

In designing a retrofit package for a house it is important to have some estimate of its existing fuel consumption, and some estimate of its fuel consumption after retrofit. These estimates involve a great number of considerations, and in some cases may be seriously in error. The Conservahome Project has highlighted the following points:

- a) It might be thought that the existing fuel consumption of the house can be determined easily from the fuel bills, but this is not always true. In the first place, the fuel bills are confidential between the home owner and the power utility company, and can be obtained only with the consent of the home owner. If the fuel bills can be obtained, then the next task is to separate the fuel consumption for space heating from that for domestic hot water heating (note that this applies when the same fuel source is used for both types of heating, as is common in Saskatchewan). The rate of fuel consumption in summer gives a rough estimate of fuel usage for domestic hot water heating, and from this the annual DHW fuel consumption can be roughly estimated. But, in most places in Saskatchewan, the gas meter is read quarterly, and the intervening monthly bills are based on estimates. Therefore, in a typical situation, there are only two gas meter readings that can be used to determine DHW usage - and these may be unrepresentative because of summer vacations.
- b) The fuel bills do not give a reliable indication of space heating fuel requirements where the house has an 'unregulated' heat source, such as a fireplace or a wood-burning stove.

- c) The heat loss performance of the house can be calculated theoretically, by careful measurement of the various components of the house. This involves the measurement of wall areas and thermal resistances, windows and their thermal resistances, infiltration levels and so on. This is fine in theory but virtually impossible in practice. In older houses that have no wall insulation there is no accurate way of estimating the thermal resistance of the wall: the choice of R2 rather than R2.5 has a 20% effect on the estimate. Even in walls that have insulation, it is difficult to assign an accurate thermal resistance where there is some obvious deterioration. Similarly, the true thermal resistance of a window cannot be estimated accurately if the storm window is poorly fitted, as is often the case. The natural infiltration rate of the house is equally uncertain; airtightness tests, using the pressurization technique, give a useful indication of the leakiness of the house envelope, but not in a form that can be used to give an accurate estimate of natural infiltration rate. More research is needed in this general area.
- d) It is instructive to compare the actual space heating requirements with the theoretical estimate. This was done on only four of the Conservahomes; the remaining two (Maidstone and Weyburn) had incomplete fuel records. In the four comparisons it was found that the theoretical analysis always predicted a fuel consumption higher than the actual value, by typically 25% to 30%. This reflects uncertainties in the estimating procedures, but the consistently high theoretical value suggests that a major effect has been consistently overlooked. Some of the discrepancy may be explained by the "sol air" effect (solar

absorption by the building envelope). Also, it may be indicative of the several small gaps in the state of knowledge.

14 TECHNICAL CONCLUSIONS

14.1 It is advisable to regard each house as a unique retrofit problem, with its own unique constraints and needs. A 'formula' approach might be successful in some instances, but in view of the individual differences of houses this approach should not be adopted without caution.

14.2 In assessing the house for retrofit, the guiding consideration should be to improve the thermal efficiency of the house without adding to the risk of long-term structural damage. In fact, a good retrofit package could be seen as an opportunity to correct faults that are already built into the house.

14.3 By combining retrofit work with necessary rehabilitation, the two aspects can be designed to complement each other - both technically and economically.

14.4 The various features of the house interact with each other, often in ways that are subtle or indirect. Retrofit work may therefore have ramifications that are not immediately obvious. A good retrofit design therefore depends on the ability of the assessor to understand the physical processes involved and the consequences of modifying these processes. This calls for a greater technical competence on the part of the assessor than has been customary in the past.

14.5 The assessment of the house is an important part of the whole retrofit process, and should be given prominence in any large retrofit programs. This will avoid undesirable long-term effects and will ensure that the retrofit money is spent to best effect.

14.6 The techniques of airtightness testing and thermographic scanning are not universally beneficial. They are not quantitative in the strictest sense of the word, and, in the majority of cases, they provide no more relevant information than can be deduced by a trained assessor from a simple visual inspection. In the few cases where the techniques are of value, they can do an excellent job. Because of the high costs of applying these techniques, some judgement is needed to define the instances where they will be of particular benefit.

14.7 Many of the new items of energy-conserving hardware are still in a developmental state, with technical and supply problems. Given time these factors can be expected to change for the better. Such changes can only be brought about if there is a continued market demand, and it might be seen as government's role to stabilize this market by using the new technologies in their large-scale programs.

14.8 Furnace technology is not developing entirely in the right direction. There is too much concern with improved efficiency and scarcely any concern with low prices and reduced capacity. The main obstacle here lies in thinking of the furnace as an isolated self-sufficient unit, rather than as a small element in the larger entity

of the house. When it is looked at in this way, the furnace becomes an interacting unit within a retrofit package. In this light, many of the current furnace developments are seen to be inappropriate. For as long as these present developments persist, the standard furnace, with its efficiency in the range of 65% to 70%, will probably be more cost-effective and more marketable.

14.9 Changes in the house heating system, or in its air management system, or even in its heating needs, may create the risk of long-term structural damage. It is in this area that the assessor has to be particularly knowledgeable in the physical processes involved. This area has not been investigated adequately. More basic research and case studies are needed.

SECTION III

STRATEGIC FINDINGS

Most of the retrofit work was put out to tender during 1980, at a time when the building industry was starting to feel the first effects of the rapid rise in mortgage rates. Therefore, it was anticipated that many builders would see this venture as an excellent opportunity to diversify into the field of retrofit. Such was not the case. There was no response at all from what might be called the 'established' builders. The only response was from small builders, of the type who normally carry one or two houses at a time, and from the 'moonlight' sector. None of the tendering builders (as far as the authors are aware) was a member of HUDAC. The following is a summary of the bids received:

Maidstone: One bid from a small contractor, who admitted difficulties in estimating the work and agreed to go ahead on the basis of 'cost plus'.

Weyburn: One bid from a medium sized contractor, but at a cost that was so high that it was taken to express a lack of interest. The retrofit work on this house was eventually managed by Saskatchewan Research Council, acting in the same way as a private home owner.

Swift Current:

Three bids, all of which were unacceptably high. Several efforts were made to induce builders from other cities to take this work. Finally, the selected bidder from the Yorkton Conservahome agreed to do this work. His eventual costs were not much different from the original best bid.

Yorkton: Two bids were received. The contract was awarded to the low bidder, who was a small builder interested in retrofit work.

Prince Albert:

Two bids were received. The contract was awarded to the low bidder, a small builder from Saskatoon who was keen to get involved in residential energy conservation.

Moose Jaw: Five bids were received, all far higher than was acceptable.

The retrofit package was modified to reduce the costs, and was resubmitted to the low bidder, who accepted. This bidder was a small builder who was interested in getting into the retrofit field.

In summary, five of the houses were retrofitted by four small builders who already had an expressed interest in retrofit, and the sixth house was retrofitted by Saskatchewan Research Council acting in the capacity of a private home owner and sub-contracting the work to a mixture of journeymen and handymen.

The lack of response from the established building sector was disappointing, but, with the benefit of hindsight, it is understandable. Most of the larger builders are not structured to deal with low-budget, single-house projects of this type. Even so, it might be argued that they ignored a very good opportunity to diversify into retrofit, in a situation which would have given them ideal conditions for technical assistance and on-the-job training. On the other hand, it has to be admitted that this aspect of the project was not promoted as well as it might have been.

Retrofit work offers obvious advantages to the building industry:

it allows diversification at a time when building starts are in decline, and it creates more opportunities for winter work, thereby allowing builders to smooth out the annual peaks and troughs of activity. Conversely, any large programs of retrofit can benefit from the involvement of the 'established' building industry. The ethical standards that are practiced through builder associations such as HUDAC or the New Home Certification Program can be brought to bear in the field of retrofit, which currently lacks any coherent form of control. Also, the larger builders, with their advantages of scale and vertical integration, may be able to reduce the costs of retrofit. This, of course, can be done only if retrofit work is conducted on a large scale. Therefore, although the building industry has shown little interest in the Conservahome Project, it can be expected to show more interest in retrofit work on a larger scale. If, or when, such programs are put into effect, the main problem will then centre on how to transfer the technical know-how to the participating builders.

Two useful lessons were learned during the tendering stage of the Project, and these should be borne in mind when future projects of this type are contemplated. First, a much greater effort should be made to involve the established building industry, by promoting the several advantages of retrofit. Secondly (and touching on a point that will be discussed later), the costs of retrofit, as applied in this project, were found to be high. In the Conservahome Project, this was a lesson that had to be learned. Many of the builders' bids, which were thought to be high in the first place, eventually proved to be realistic for the levels of retrofit that were applied.

The standard of workmanship in the Project was generally very good. Part of this was due to the stringent inspection procedures, but most of it was due to the enthusiasm and craftsmanship of the builders. The best workmanship came from the small companies, where the builders took an active part in the work at site, and were usually there to control the quality. These small companies (three in number), were all interested in understanding the 'hows' and 'whys' of what they were doing.

Because of the exploratory nature of the Project, it is almost certain that it attracted the best elements of the small building industry: builders who were interested in energy conservation and were receptive to new ideas. In larger retrofit projects, involving a more representative selection of the building industry, there would probably be more resistance to adopting the new techniques of retrofit.

When the contracts were placed with the builders, each builder was taken around the house and was given a detailed explanation of the work required, and the underlying principles. From the subsequent performance of the builders it can be concluded that only a small part of this information was retained, and still less was passed on to the sub-trades. When faced with radical departures from accepted building practice, the builders tended to become uncertain. Some reverted to standard building practice, while others did the required work, but not with any great degree of conviction. Neither response was suited to the objective of the project. Accordingly, SRC and SHC made several visits to each site during construction. A considerable amount of time was spent in discussing and explaining the requirements and the underlying reasons for them.

The builders were most appreciative and responsive, and this appears to have been a very effective way of transferring the technology to the trades.

The lesson from this is clear: it is unreasonable to expect builders to grasp several new concepts, and perhaps several new technologies, on the basis of two or three hours instruction. It is also unreasonable to expect that this same information will be transmitted accurately from the builder to his sub-trades. The technology transfer process is an important factor at this level of the retrofit process, and a well thought-out approach needs to be developed.

17. THE EFFECT OF CODES AND BY-LAWS

When application is made for permits (gas, electrical, plumbing or building), to do work on an older house, the issuing authority generally uses this as an opportunity to have the house brought up to acceptable standards. As a result, the unwary owner might suddenly be faced with the costs of a major overhaul of one or more of the house utilities.

The Weyburn house demonstrates some of the pitfalls. Some basic upgrading of the electrical and plumbing systems was planned for this house, based on an inspection of the visible parts of these systems. The planned work was designed in consultation with the local electrical and plumbing trades, and appeared to be reasonable. However, as work progressed on the house, it soon became clear that most of the hidden parts of these utilities were defective. The inspectors condemned both the plumbing and electrical utilities, and called for a complete overhaul.

The attitude of the inspection authorities is sensible. A house

cannot be allowed to continue in a condition that might be hazardous to the occupants, and the permit system offers an effective means of keeping an eye on the condition of the housing stock. The inspectors appear to exercise some degree of flexibility within a fixed set of safety guidelines, and will not insist on some trivial ruling if it is likely to involve major reconstruction. Generally, they are fairly lenient towards private home owners in this respect. However, in the Conservahome Project, which was known to be a government project, SRC experienced some difficulty in securing the same level of leniency. There was a slightly more strict interpretation of codes and by-laws, which in some cases is believed to have added significantly to the cost of the work.

In a combined program of retrofit and rehabilitation, the main effect of codes and by-laws is to increase the cost of the rehabilitation work. This is particularly true in houses built before 1945. The codes and by-laws generally have little effect on the retrofit work, as such.

In the odd instance, where retrofit work might infringe the codes or by-laws, the administering authority may decide to give a dispensation, provided that it does not lead to a hazardous situation or an undesirable precedent. In the Swift Current house, for instance, permission was given to use the domestic hot water tank for space heating. In other cases, outside the Conservahome Project, retrofit work has sometimes contravened the existing by-laws. One such example occurred when a house was retrofitted with a framed insulated wall, added to the outside. This happened to reduce the side-lot clearance below the by-law minimum. The exterior insulation strategy was adopted on the Prince Albert and Swift Current Conservahomes, but the local by-laws were examined first to see whether this would be acceptable.

In larger programs, where retrofit and rehabilitation are to be combined, the lessons of the Conservahome Project emphasize the need for careful appraisal of the utilities at the outset. It is important to have a professional inspection of the various utilities as part of the general appraisal of the house. The main purpose of these inspections should be to define the work (and costs) needed to bring the house up to an acceptable standard. In some cases, particularly in older houses, the cost of a major overhaul of the utility systems may be the deciding factor in whether to rehabilitate or demolish the house.

18. AN APPRAISAL OF THE ROLE OF HOUSING AGENCIES IN RETROFIT

Because of the size and unusual nature of this project, it cannot be considered typical of the programs normally undertaken by housing agencies, and many of the experiences of the project are therefore irrelevant. Nevertheless, the project did highlight a number of factors that should be considered by housing agencies when embarking on larger retrofit programs.

18.1 Contract Documents

Detailed drawings and contract specifications were prepared for each of the six houses. This was justifiable for an exploratory project with an associated demonstrational program, but it would probably be too costly for routine retrofit programs. The following are some of the main considerations relating to the use of contract documents:

- a) At the moment, small builders are showing the greatest interest in retrofit work. These builders are not accustomed to dealing with the extensive and detailed contract specifications that were used on this Project. Some of the builders in the Project found

it difficult to estimate costs on the basis of the specifications, some builders were obviously deterred by the specifications, and some builders may have inflated their bids as a way of covering themselves against something of this complexity.

- b) It was assumed, in the early stages of the Project, that a detailed specification of the work was all that the builder would need to allow him to do the retrofit work effectively. The Contract Documents were therefore expected to serve a triple role: as a legal document, as an instruction to the builder, and as a medium for technology transfer. Experience has shown that the Contract Documents cannot fulfill the function of technology transfer. To express this point unscientifically: an hour spent at site, explaining the technicalities to the builder and sub-trades, is probably more effective than twenty hours spent on writing a precise specification.
- c) If future retrofit projects are based on detailed Contract Document specifications, who is going to write them? The writer must be familiar with all the techniques of retrofit, he must have an intimate knowledge of the existing house, and he must have all the usual skills of the Contract Document writer. This is an impracticable combination, but it is the only combination that will work if retrofit is to be controlled by written specifications.

18.2 The good-owner policy

Saskatchewan Housing Corporation has a 'good owner' policy, which is essentially an obligation to put buildings in good order before transferring ownership. This policy had a substantial bearing on the rehabilitation requirements of the project. It is possible that many similar

housing agencies have a similar 'good owner' policy, and it is therefore appropriate to discuss one of the consequences here.

The 'good owner' policy becomes particularly questionable in older houses, that have a remaining lifetime of twenty years or less. The remaining lifetime of the house should be considered when designing the retrofit package; it should also be considered when deciding on the extent of rehabilitation work. In an older house, for instance, a sagging floor is not nice to live with, but if it does not constitute a hazard it might be tolerable for the remaining life span of the house.

Ideally, both the retrofit and the rehabilitation work should be designed to make the house safe, liveable and optimally economic over its remaining life span. In some cases, the housing agency might have to be prepared to tolerate non-hazardous defects.

18.3 Inspection standards

In the original planning of the project it was intended that the local SHC inspectors should control the standards of workmanship on the Conservahomes. To this end, Saskatchewan Research Council conducted a one-day workshop for all the SHC inspectors, to acquaint them with the basic principles of retrofit and to introduce them to some of the new technologies. Experience has shown that this was not effective. Retrofit technology has to be seen as a radical change in building practice. It is not a simple extension of current practices, and it involves many subtleties that cannot be conveyed across a desk or on a blackboard. It is recommended that housing agencies give careful consideration to the technology transfer needs associated with retrofit programs.

19.1 The success of future retrofit programs, on the large scale, will be influenced by the response of the 'established' building industry. It is doubtful that the small, specialized companies will be able to handle the large programs that will need to be put in place. The larger 'established' builders have shown a general reluctance to get involved in retrofit. This may be due partly to the scale on which retrofit has been conducted so far. The reluctance may also stem from an appreciation of the many issues that need to be resolved before major diversification is justified.

19.2 Housing agencies may encounter some problems in adapting to the requirements of retrofit programs. The greatest problem concerns technology transfer to the inspectors who will have to control the actual retrofit work. One effective way of tackling this problem is to start with moderately sized pilot projects, serving partly as training schemes.

SECTION IV

ECONOMIC FINDINGS

The builders were asked to keep a fairly detailed record of costs, and were also asked to try to itemize these costs under the various job headings. The response was varied: one builder submitted a single page of barely decipherable figures with no explanation; the Weyburn house, which was retrofitted under SRC management, produced a detailed set of records that could be broken down fairly accurately according to job type. Generally though, the builders found it difficult to give a good cost breakdown. To demonstrate the problem, consider what happens when a framing sub-contractor is involved in retrofit work: the framing costs might be spread over several different retrofit and rehabilitation jobs, and it is virtually impossible to produce an accurate breakdown. Therefore, in many cases, the cost estimates given in this section are little more than inspired guesswork - on the part of the builder and on the part of SRC.

The second problem is a major one, and concerns the breakdown of costs according to retrofit and rehabilitation. When the house is retrofitted and rehabilitated simultaneously, it has already been pointed out that one task should complement the other. This makes it difficult to draw a dividing line between the two types of work. For instance, the condition of the interior walls in the Maidstone house made it desirable to remove the drywall, insulate the exterior walls, then install new drywall. How much of this work should be allocated to retrofit, and how much to rehabilitation? There is no good answer.

For the purposes of this report it has been decided to break down the project costs according to the following procedure: any work or material costs that produce a direct improvement in the thermal performance of the house are listed under retrofit, and all other costs are listed under rehabilitation. The advantage of this breakdown is that it provides all the figures that are needed for other types of breakdowns. For example, it might be decided that the full cost of retrofit is given more accurately by adding 25% of the rehabilitation costs to the direct retrofit costs.

The costs of the project are summarized in Table III. This table gives the purchase cost of the houses, the direct retrofit costs, the rehabilitation costs and the decoration costs. This last cost item was incurred as part of the demonstrational program of the project, and would not normally be included in the rehabilitation costs.

The high retrofit costs reflect the dual nature of the project. The allocation of retrofit levels across the six houses was determined by technical, economic and demonstrational considerations, as described in section 6. This led to the selection of four high-level, one medium-level and one low-level retrofit. Referring to Table III, the high-level retrofits fell into a cost range of \$10,300 to \$13,800. The medium-level retrofit at Yorkton had an associated cost of \$8,692, and the low-level retrofit at Moose Jaw had an associated cost of \$2,170. The high-level retrofit packages consisted of a fairly thorough upgrading of the house envelope, the air management system and the heating system. Relatively few home owners would be prepared, or could afford, to do retrofit work to this degree. The intention was primarily demonstrational, aimed at

Conservahome location	Age	Purchase cost	Direct retrofit cost	Rehab. cost	Decor. cost	Total
Maidstone	1920	33,300	10,522	32,478	2,218	45,218
Weyburn	1929	37,000	13,780	20,325	1,230	35,335
Swift Current	1946	29,660	13,390	9,920	3,483	26,793
Yorkton	1963	48,500	8,692	2,248	905	11,845
Prince Albert	1966	52,000	10,368	3,110	1,267	17,245*
Moose Jaw	1976	50,000	2,170	1,220	600	3,990

* This total includes \$2,500 of remedial retrofit work that should have been done within the costs allocated to direct retrofit.

Table III Breakdown of main cost items on the Conservahomes.

presenting a wide range of options to the general public and the building industry.

Generally, the costs in Table III are probably higher than would normally be experienced by the average home owner. This is due to several factors arising from the unusual nature of the project:

- a) The innovative techniques and hardware were strange to practically all of the builders, and their high costs are partly a consequence of the 'learning curve' effect.
- b) Many of the builders were not accustomed to dealing with Contract Document specifications of the type used in the Project, and it is possible that the costs were inflated to cover against all eventualities.
- c) The insistence on high standards of workmanship, and rigid inspections, added to the actual cost of the work.
- d) SHC's good-owner policy is believed to have added to the cost of rehabilitation in several houses.
- e) The inspection authorities and local municipalities imposed codes and by-laws more stringently than in the normal home owner situation.
- f) The typical home owner would normally act as his own general contractor, and therefore would not incur the extra overheads of contract management.

Taking these various factors into account, it is possible that, in a typical home owner situation, the costs of both retrofit and rehabilitation would be about 20% to 30% less than shown in Table III. However, when using this data to estimate potential costs to home owners, allowance

should be made for the fact that most retrofit involves a certain amount of rehabilitation work. The actual amount, and its associated cost, will vary according to individual circumstances, and it would be misleading to give any indication of the cost correction that should be applied.

As a general commentary on the retrofit costs, these can obviously be reduced considerably if the home owner is able to do the work himself, and does not count the cost of his labour. Tables given later in this report show that the home owner could save typically 50% to 60% by doing the work himself. So far, a large amount of retrofit work has been accomplished in this way, and the costs that have been brought to public attention are often based on this situation. This tends to give a misleading idea of the true costs of retrofit to that large section of the general public that does not have the requisite skills. One of the benefits of this project is that it has established the costs of retrofit as conducted by the building industry under the control of a general contractor. This, subject to the reservations given above, is probably more typical of how the average home owner would have to get the work done.

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BREAKDOWN OF RETROFIT COSTS

The purpose of this section is to give a general summary of the retrofit costs and economics.

The main elements of the retrofit costs and savings are given for each house in the following tables, numbered IV to IX. Note that these

TABLE IV. RETROFIT ANALYSIS, MAIDSTONE

Retrofit Component	Labour \$	Materials \$	Total \$
Basement	250	257	507
Walls and floor	1644	1283	2927
Attic	443	315	758
Doors	397	1042	1439
Windows	1277	1540	2817
Furnace and duct work	525	323	848
Air heat exchanger	80	385	465
Domestic hot water system	340	421	761
Totals:	4956	5566	10522

Retrofit Component	Cost of heat loss		Annual saving \$
	Original \$	Retrofit \$	
Basement or floor		15	
Walls	total estimated transmission loss =	43	
Attic		13	
Doors		2	
Windows		34	914
Infiltration/ventilation	74	18	56
Furnace heat losses	535	45	490
Totals:	1630	170	1460

Reduction in space heating costs = 90%

Direct payback of retrofit = 7.2 years

TABLE V. RETROFIT ANALYSIS, WEYBURN

Retrofit Component	Labour \$	Materials \$	Total \$
Basement	1654	1016	2670
Walls	1586	224	1810
Attic	385	300	685
Attic hatch relocation	330	85	415
Doors	240	810	1050
Windows	2324	866	3190
Interior sealing	803	46	849
Fireplace retrofit	400	110	510
Furnace and DHW replacement	787	263	1050
Miscellaneous	1137	414	1551
Totals:	9646	4134	13780

Retrofit Component	Cost of heat loss		Annual Saving \$
	Original \$	Retrofit \$	
Basement	111	26	85
Walls	116	32	84
Attic	49	12	37
Doors	14	1	13
Windows	53	34	19
Infiltration/ventilation	71	18	53
Furnace heat losses	236	52	184
Totals:	650	175	475

Reduction in space heating costs: = 73%

Direct payback on retrofit = 29.2 years

TABLE VI. RETROFIT ANALYSIS, SWIFT CURRENT

Retrofit Component	Labour \$	Materials \$	Total \$
Basement (exterior top 4ft)	520	645	1165
Walls	890	1745	2635
Attic	800	500	1300
Doors	470	230	700
Windows	1200	800	2000
DHW tank enclosure	100	170	270
Combined DHW & Space Heat System			3500
Air heat exchanger	200	530	730
Associated electrical work			1090
Totals:	4180	4650	13390

Retrofit Component	Cost of heat loss		Annual Saving \$
	Original \$	Retrofit \$	
Basement	73	15	58
Walls	45	10	35
Attic	53	10	43
Doors	10	4	6
Windows	31	12	19
Infiltration/ventilation	53	6	47
Heating system losses	101	23	78
Totals:	366	80	286

Reduction in space heating costs = 78%

Direct payback on retrofit = 46.8 years

TABLE VII. RETROFIT ANALYSIS, YORKTON

Retrofit Component	Labour \$	Materials \$	Total \$
Basement	2507	1436	3943
Walls (sealing)	520	200	720
Attic	659	415	1074
Doors	80	20	100
Windows	900	420	1320
Furnace room	420	225	645
Air heat exchanger	260	630	890
Totals:	5346	3346	8692

Retrofit Component	Cost of heat loss		Annual Saving \$
	Original \$	Retrofit \$	
Basement	98	24	74
Walls	55	49	6
Attic	62	12	50
Doors	6	5	1
Windows	35	20	15
Infiltration/ventilation	69	17	52
Furnace heat losses	115	46	59
Totals:	440	173	267

Reduction in space heating costs = 61%

Direct payback on retrofit = 32.5 years

TABLE VIII. RETROFIT ANALYSIS, PRINCE ALBERT

Retrofit Component	Labour \$	Materials \$	Total \$
Basement (exterior)	564	980	1544
Walls (vapour barrier)	312	120	432
(frame and insulation)	538	454	992
Attic	224	430	654
Attic hatch relocation	52	114	166
Doors	156	794	950
Windows	428	1990	2418
Furnace room	152	248	400
Furnace replacement	485	730	1215
Duct modifications	150	75	225
DHW tank	60	223	283
Air heat exchanger	250	530	780
Miscellaneous electrical	206	103	309
Totals:	3577	6791	10368

Retrofit Component	Cost of heat loss		Annual Saving \$
	Original \$	Retrofit \$	
Basement	49	15	34
Walls	41	11	30
Attic	28	7	21
Doors	6	1	5
Windows	32	17	15
Infiltration/ventilation	51	8	43
Furnace heat losses	93	16	77
Totals:	300	75	225

Reduction in space heating costs = 75%

Direct payback on retrofit = 46.1 years

TABLE IX. RETROFIT ANALYSIS, MOOSE JAW

Retrofit Component	Labour \$	Materials \$	Total \$
Basement (modify insulation)	199	178	377
Walls (seal)	10	5	15
Attic	415	665	1080
Doors	55	43	98
Windows	175	80	255
Night set-back thermostat	0	130	130
Furnace tune-up	50	0	50
Air management system	115	50	165
Totals:	1019	1151	2170

Retrofit Component	Cost of heat loss		Annual Saving \$
	Original \$	Retrofit \$	
Basement	51	22	29
Walls	38	37	1
Attic	23	12	11
Doors	1	1	0
Windows	32	19	13
Infiltration/ventilation	63	17	46
Furnace heat losses	107	49	58
Totals:	315	157	158

Reduction in space heating costs = 50%

Direct payback on retrofit = 13.7 years

tables use the direct retrofit costs as defined earlier, and do not include any rehabilitation work associated with the retrofit. Each table has a summary of the costs of retrofit, a summary of the fuel cost savings, an estimate of the reduction in space heating costs and an indication of the payback. Note that the fuel costs are based on 1981 natural gas rates in Saskatchewan, except for Maidstone, in which the fuel costs are based on 1981 oil costs in Saskatchewan. The direct payback, as given in each table, is the total cost of retrofit divided by the fuel cost saving in the first year - commonly referred to as the uncorrected payback.

21.1 Basements

The cost of retrofit ranges from \$377 to \$3943. The low cost corresponds to a simple addition of insulation in an already-developed basement with easy access to the wall interior. The high cost corresponds to a complete framing and insulating job on an undeveloped basement. In the two cases where the basement was insulated on the exterior (Swift Current and Prince Albert), this work was confined to the top 4 ft. of basement wall, and was included in the general exterior insulation work. The direct retrofit costs were in the range \$1165 to \$1544. This does not include the non-direct costs of excavation, removal of concrete work, relocation of gas service inlets and so on. Basement retrofit generally gives a relatively high saving on fuel bills.

21.2 Walls

When the walls are insulated on the exterior, as in Prince Albert and Swift Current, the costs are in the range of \$1400 to \$2600, depend-

ing on the technique used. The high cost of styrofoam SM is an important factor, and makes it more economical to use a wood frame with R20 glass fibre batt. The total cost of re-skinning the Swift Current and Prince Albert houses was \$3,800 and \$2,968 respectively. Both costs include the vapour barrier and the work on the top 4 ft. of basement wall. They do not include the costs of siding, which in each case was a justifiable rehabilitation cost. An extra cost, somewhere around \$2,000, should be added to these figures to cover the costs of excavation, soffit modification, step removal, concrete removal, relocation of service inlets, extension of door and window frames, and replacement of the various facilities on completion of the work. The total cost of a re-skinned wall is therefore in the range \$5,000 to \$6,000.

At Maidstone, the cost of wall and floor retrofit was \$2,927. This includes the construction of an air-vapour barrier on these surfaces, and insulation with glass fibre batt. This figure does not include the removal and replacement of drywall, which can be taken as justifiable rehabilitation cost in this instance.

The walls on the Weyburn house were insulated with vermiculite. This insulation material was chosen because of its performance under conditions of moisture accumulation - which is a distinct risk in this house because of the total absence of vapour barrier. The vermiculite was poured into the walls from inside the attic, and through cored holes beneath windows and other inaccessible parts. It takes a great deal of effort to do this job properly, particularly when the wall surfaces are in very good condition and should not be spoiled. The high labour costs, \$1,586, are indicative of the effort that is needed.

At Moose Jaw and Yorkton no insulation was added to the walls. The wall costs on these two houses were \$15 and \$720 respectively, and arose from airtightness sealing work. At Moose Jaw the sealing work was restricted to easily accessible parts of the structure. At Yorkton a thorough sealing job was done on the complete wall envelope, including sealing behind baseboards and at the joint of concrete foundation and floor joists. This is a labour-intensive job, as can be seen from the high labour costs. It is worth commenting that, at Moose Jaw, it was originally proposed to seal around the joist-concrete joints, but this part of the work was cancelled when it was discovered that the cost would be at least \$250.

Wall retrofit generally has a long payback, particularly in newer housing stock where the existing insulation levels are moderately good and new insulation cannot be added without a major operation.

21.3 Attics

Similar work was done on the attics at Yorkton, Prince Albert and Moose Jaw. This consisted of sealing all accessible air infiltration openings, then adding typically R20 to R30 of extra insulation. The material costs range from \$415 to \$665, reflecting the size of the attic and the amount of added material. The labour costs range from \$224 to \$659. Some of this is due to the difference in labour rates, and some is due to the complexity of the sealing work. The total costs of attic retrofit range from \$654 to \$1,080.

The Maidstone attic was insulated in two stages: batt insulation was installed under the attic floor, and loose fill was installed above. This

is reflected in the relatively high cost of \$758.

The Swift Current house had a half-story attic construction, creating several problems in the insulation and vapour barrier work. The high cost of this attic work, \$1,300, includes both insulation and a new vapour barrier.

The Weyburn house had a plaster-on-lath ceiling with no vapour barrier and with some extensive openings along the top of the partition wall. It was judged impracticable to install a vapour barrier, and the cost of \$685 covers extensive sealing work as well as insulation.

21.4 Attic Hatches

The cost of sealing and insulating the attic hatch is buried in the total attic retrofit cost, but is probably around \$20 to \$30. When the attic hatch is relocated on the roof gable, the cost can range from \$166 to \$415 according to the constructional problems involved.

21.5 Doors

A good sealing job, as done at Yorkton and Moose Jaw, costs typically \$80 to \$100. A mixed approach, involving part replacement and part repair, costs typically \$700 to \$950, as at Swift Current and Prince Albert. Total door replacement costs depend on the quality of the replacement. The high quality, double thermal units at Maidstone had an installed cost of \$1,439. The solid core replacements at Weyburn had an installed cost of \$1,050.

Doors have a trivial effect on fuel savings, and are probably one of the least cost-effective of all retrofit measures. It is advisable to keep door retrofit costs to a minimum, and to concentrate more on the door seals than on the transmission heat losses through the door.

21.6 Windows:

The window retrofit work was far too detailed to discuss here. A combination of techniques, including repair, replacement, upgrading and elimination, was practiced on most of the houses. Moose Jaw had the lowest window retrofit costs at \$255. This consisted of improving the seals and providing sash locks. Yorkton was next, at a cost of \$1,320. This included a mixed upgrading of some windows to triple-glaze and quadruple glaze, and also some improvement in the seals. The windows at Weyburn and Swift Current were subjected to a combination of repair, re-sealing and replacement. The difference in costs - \$2,000 at Swift Current and \$3,190 at Weyburn - is due mainly to the different numbers of windows in the houses.

The majority of windows in the Prince Albert house were replaced by new, high-quality units, at a total cost of \$2,418 for the whole retrofit package. At Maidstone, several windows were eliminated, and the rest (5 altogether) were replaced with high-quality units. The total cost of retrofit was \$2,817.

Basement windows were generally of deplorable quality, and usually showed more deterioration than other house windows. Particular attention was paid to these windows, the cost being included in the figures given above.

Window retrofit is usually a major cost item, if it is done properly. The direct payback, as defined earlier, is typically in the range of 80 to 150 years. This is due partly to the high cost of window retrofit, and partly to the poor thermal performance of even a 'good' window. If the existing house windows are in fairly poor condition, it is debatable

whether they should be upgraded or replaced. Upgrading appears to cost about 20% to 40% less than replacement, depending on a large number of factors. On balance, therefore, it might sometimes be preferable to bear the extra costs of replacement. This could result in better thermal performance, better infiltration performance, and extended window life. The Conservahome Project has shown that window retrofit is a highly complex issue - both technically and economically. There needs to be far more research into this matter.

21.7 Furnaces

A furnace tune-up costs \$50, according to Moose Jaw data. This was done by a local tradesman and does not include any significant travel costs. At Maidstone, the furnace costs included a tune-up of the oil furnace, installation of flame-head retention burner, re-routing of ductwork, and insulation of the ductwork (due to the strategy of operating the basement as a cold crawl space). The total cost of this work was \$848, and a more detailed breakdown would be difficult.

The installed cost of a new, standard furnace at Weyburn was about \$700, and the comparative cost of the new, energy-efficient furnace at Prince Albert was \$1,215. Bearing in mind the reduced fuel consumption on both houses, and the corresponding reduction in furnace heat losses, the extra cost of the energy-efficient furnace makes it the less cost-effective of the two options. It should be noted that the furnace heat losses given in the tables show a considerable saving as a result of retrofit. Very little of this is due to actual improvements in the furnace. Most of the saving arises from the reduced heating needs of the retrofitted house.

The existing furnace at Swift Current was removed, and the replacement heating system consisted of a water coil mounted in the air circulation plenum. This coil was supplied with hot water from the domestic hot water tank. The total cost of this system was \$3,500, not including some electrical changes, but including extensive duct work.

21.8 Furnace Rooms

These should be considered only when the house has been brought to a fairly high level of airtightness. The cost of the furnace room ranges from \$400 at Prince Albert to \$645 at Yorkton. The size of the furnace room is an influential factor here. At Swift Current, the 'furnace room' was actually a small airtight closet built around the domestic water tank, at a cost of \$270. Note that all these costs exclude the ducting for draft air and combustion air. This air supply is essential in a furnace room. The costs are included elsewhere in the tables.

The furnace room is an effective way of improving the seasonal efficiency of the furnace, and it also reduces the infiltration through the main house structure. It is difficult to make an accurate assessment of the cost-effectiveness of this measure.

21.9 Air heat exchangers and air management

The installed cost of air heat exchangers ranges from \$465 to \$890, according to the type of heat exchanger and the degree of complexity of the associated ductwork. The lowest cost was incurred at Maidstone, where a small Lossnay unit was installed in the house wall with no additional ducting. The Lossnay literature indicates that this is one

way of installing the heat exchanger, though it does not advocate it. The unit was installed in this way at Maidstone as a last-minute demonstrational feature, in the full knowledge that it would have to be ducted at a later stage. The stuffiness of the house during the demonstrational phase has confirmed the need for proper ducting, and this is expected to cost about \$150.

A basic air management system, consisting of an exhaust and fresh air inlet, was installed in the Moose Jaw house. The cost was \$165, inclusive of the various dampers and controls.

21.10 Fireplaces

The Weyburn fireplace was a major source of air infiltration. On inspection, it was discovered to have been installed incorrectly. It cost \$510 to correct the situation.

22 DISCUSSION OF COST BENEFITS AND RETROFIT STRATEGIES

Table X gives a summary of the basic cost benefit data for each of the six retrofit packages. The data are taken from Tables IV to IX and are subject to the limitations discussed earlier.

House	Retrofit level	Retrofit cost (\$)	Annual saving (\$)	Payback (yrs) *	Estimated Space heat reduction
Maidstone	high	10,522	1,460	7.2	90%
Weyburn	high	13,780	475	29.2	73
Swift Current	high	13,390	286	46.8	78
Prince Albert	high	10,368	225	46.1	75
Yorkton	medium	8,692	267	32.5	61
Moose Jaw	low	2,170	158	13.7	50

* Payback is uncorrected and is retrofit cost divided by first year savings.

TABLE X. COST BENEFIT DATA FOR RETROFIT PACKAGES

The data are not extensive enough to permit quantification of any trends. It is generally accepted that a process of diminishing returns applies to retrofit, so that the cost-benefits tend to decrease as the level of retrofit increases. The above data are generally consistent with such a trend. The Maidstone house is an exception; its relatively high cost benefit is due primarily to the large fuel saving, which in turn is due to the excessively low thermal efficiency of the original structure. The Weyburn house shows a similar tendency for the same reasons, though its effect is not so pronounced. The two oldest houses in the project therefore show a trend that is consistent with a poor thermal performance of the original structure. The payback data indicate

that high levels of retrofit may be relatively cost effective in such cases. Note, however, that the project has not explored the cost effectiveness of lower levels of retrofit on older houses.

Originally, it was hoped that the data from the project would be extensive enough, and detailed enough, to permit an analysis of individual retrofit options. If this could have been done, then it would have been possible to discuss the cost effectiveness of individual options such as sealing, window retrofit, etc. It would also have been possible to rank the various options according to cost effectiveness, or to indicate what strategies home owners should follow in houses of various ages. Unfortunately, there are a number of factors that prevent such an analysis:

- a) The cost breakdowns in Tables IV to IX already contain an element of error, due to the factors that were discussed in Section 20. A more detailed breakdown of costs would involve further assumptions and further errors. For example: most of the attic work in this project consisted of two separate components: sealing and insulation. One affects the infiltration heat loss of the house and should be considered part of the general sealing package. The other affects the transmission heat loss through the ceiling. The cost information supplied by the builders was not sufficiently detailed to permit the accurate division of costs that would be needed in this case.

- b) Apart from the cost problem, it is also difficult to assess the detailed thermal improvements produced by individual retrofit options. Consider windows for example: windows lose heat by infiltration and conduction. In windows in older houses the infiltration heat loss is probably of the same magnitude as the conductive heat loss. Therefore, when a window is upgraded, both its infiltration and conduction performance will be affected. The improvement in conduction performance can be estimated fairly accurately, but the improvement in infiltration performance is totally uncertain. The infiltration performance of the windows cannot be isolated from that of the house as a whole, unless special controlled tests are conducted. Accordingly, it is virtually impossible to say how much energy is saved by window retrofit, and the same argument applies, in some degree, to most of the retrofit options. The best that can be done, within the current state of the art, is to group all the infiltration improvements together, as was done in the preparation of Tables IV to IX. But even this is an estimate, since the airtightness tests do not give a reliable indication of natural infiltration rates.
- c) Even if the above problems could be overcome, and if an accurate cost-benefit figure could be assigned to each of the retrofit measures used in the project, these figures would still have to be treated with caution. The cost benefit of a particular retrofit measure is influenced appreciably by the thermal performance of all the other components of the house envelope, as well as the

performance of the heating system. These vary from house to house, and therefore the cost benefit of any retrofit measure will also vary from house to house. The data on this effect are limited, and the magnitude of the effect cannot be estimated with any accuracy, but a variation of cost benefit over a range of two-to-one would appear to be possible. Thus, for a particular retrofit measure, the cost benefit in one situation may be totally misleading when applied to another situation.

- d) If a particular retrofit measure has no 'universal' or 'typical' cost benefit associated with it, then it is unrealistic to attempt to rank the various measures according to cost benefit. The ranking might apply to a very narrow range of house designs, but outside this range it might be totally inapplicable. Given extensive basic studies on a statistically significant number of houses, it might be possible to identify a 'representative' ranking of options that could be applied to a large number of houses of similar construction. On their own, the six houses of the Conservahome Project do not constitute an adequate basis for such a ranking.

In view of all these considerations, it is concluded that the data from the Conservahome project do not allow an analysis of the cost-benefit of individual retrofit options. A ranking of retrofit options, if such could be achieved, would be of considerable help to implementing agencies in planning their retrofit strategies. It would also simplify the problems of general technology transfer. The ideal ranking would consist of a list of retrofit options arranged in decreasing order of cost effectiveness, or a series of

retrofit packages based on a series of increasing ceiling costs. The latter alternative might take the form of: if you have \$1,000 to spend, do such and such; if you have \$2,000 to spend, do such and such, etc. It would have been very convenient if the Conservahome Project could have produced either type of 'shopping list'. However, it has proven very difficult to assess the cost-effectiveness of various options. This is understandable given the decision at the onset of the program to treat each house as a system and to implement the original package of retrofit measures despite their high cost.

If the cost-effectiveness ranking approach is to be pursued, then a considerable amount of further research will be needed. Retrofit work will have to be done on a statistically significant number of houses, to determine "average" or "typical" cost-benefits. This work will have to be done within fixed budgets set at various levels. Fundamental studies will have to be conducted, in research-oriented retrofit projects, to isolate the costs and energy savings of individual retrofit measures.

However, the author recommends that implementing agencies should give some thought to the advisability of the cost-effective approach. The Conservahome Project has indicated that such an approach fails to take account of the various interactions in the house 'system', and may produce undesirable side effects. The systems approach helps to avoid such effects, and tends to produce an upgraded house that is more viable in the long term. This approach would be more difficult to implement, since it requires a relatively individual treatment of each house - as an individual system. But it would tend to improve the credibility of retrofit by avoiding major errors. If the implementing agencies decide to adopt the 'systems' approach, then a whole infrastructure has to be established to handle it. This infrastructure will have to be built around an efficient, high-quality auditing

and inspection service. This will require trained auditors, a well-designed auditing technique, computer aids and trained inspectors. Some considerable development will be needed before the technical components are refined to the level that is required. Also, it will take several years to establish the right sort of training schemes and technology transfer systems to produce the trained manpower.

23 ECONOMIC CONCLUSIONS

23.1 Four of the Conservahomes have been subjected to high-level, one to medium-level and one to low-level retrofit. The costs of high-level retrofit range from \$10,300 to \$13,800. The cost of medium-level retrofit was close to \$8,700, and that of the low-level retrofit was close to \$2,200. The high-level retrofits will produce an estimated reduction in space heating costs ranging from 73% to 90%. The medium-level retrofit will produce an estimated reduction of 61%, and the low-level retrofit will produce an estimated reduction of 50%. The uncorrected payback ranges from 7.2 to 46.8 years for the high-level retrofit, and is 32.5 years and 13.7 years respectively for the medium and low-level retrofits.

23.2 The retrofit work was conducted mostly by building trades working under general contractors, and subject to stringent technical requirements and control. The costs are therefore atypical of what the home owner might expect. It is estimated that, in a typical home owner situation, the quoted retrofit costs might be reduced by 20% to 30%, if the home

owner has all the work done by the building trades. On the other hand, if the home owner does all the work himself, the costs could be reduced by 50% to 60%.

23.3 The Conservahomes were too few in number and covered too great a range of configurations to permit any detailed extrapolation of the economic findings. In particular, it has not been possible to examine the relation between cost-effectiveness and level of retrofit. It has not been possible to analyse the cost-effectiveness of individual retrofit measures, nor to rank these measures in order of cost-effectiveness. Some of the detailed problems of such a ranking have been discussed.

24 RECOMMENDATIONS

24.1 In implementing retrofit on a large scale, the technical constraints should be taken into consideration in parallel with the economic ones. It is recommended that implementing agencies adopt strategies that, in the first place, acknowledge the technical requirements of the house as a viable, interacting system, and in the second place try to achieve maximum cost benefits within the technical constraints.

24.2 The treatment of the house as a viable, interacting system requires carefully designed auditing procedures and properly trained auditing personnel. This will require three parallel efforts: the design and development of an auditing system, the development of computer aids for auditing, and the selection and training of personnel. These aspects are now being pursued in a number of federal government programs.

24.3 If large retrofit programs are to be effective, they must utilize the skills of the established building industry. This will involve two factors: first, some training and certification system would be desirable, to acquaint the industry with the new techniques and equipment. Secondly, some careful consideration has to be given to setting up the retrofit programs in a way that will be acceptable to the building industry. It is recommended that pilot schemes and studies be set up to cover these two aspects.

24.4 The furnace trades have been identified as a major target for technology transfer. It is recommended that this problem be attacked through the training colleges. Two initiatives are required: the first directed at the trainee trades and the second directed at upgrading the existing trades.

24.5 It is recommended that training schemes be set up to upgrade the skills of building inspectors in the area of retrofit.

24.6 A study of existing building codes and by-laws is recommended, on a provincial basis. The aim would be first to identify the codes and by-laws that restrict good energy conservation practices, and secondly to consider ways of modifying them.

24.7 The study has identified air heat exchangers and natural gas furnaces as items of equipment requiring further development. It is recommended that support be given to the development of cheaper, more compact and more reliable designs of heat exchangers. It is also recommended that furnace manufacturers be encouraged to develop units that

are better sized to the lower heating requirements of energy-efficient houses.

24.8 The various technology transfer initiatives, enumerated above, cannot be put in place immediately. It will first be necessary to train instructors and set up the right sort of infrastructures to deliver the technology transfer. Since this may take a year or two, it is recommended that it be pursued as a matter of high priority.

24.9 The Conservahome Project was, in essence, a small superficial study of some of the problems associated with retrofit. It was conducted within a demonstrational context and cannot be regarded as definitive. It has shown that a number of important technical factors exist and need to be studied. What is more, these studies have to be conducted on existing homes, but in a more controlled research environment. There is a profound lack of sound technical and scientific information in the area of retrofit. The needs fall into two categories:

- i) Research aimed at defining thermal performance of individual components, before and after retrofit, to provide the information needed for computer/audit programs and design.
- ii) Research aimed at defining and avoiding problems associated with retrofit, such as poor air quality, moisture problems, furnace problems, etc.

It is recommended that extensive R & D programs be established to tackle the wide range of problems and technical needs associated with retrofit.